Recent advances in adaptive sequential Monte Carlo methods

Alexis Quesada-Arencibia
José Carlos Rodríguez
Roberto Moreno-Díaz
Roberto Moreno-Díaz jr. (Eds.)

EUROCAST 2017

Computer Aided Systems Theory

EXTENDED ABSTRACTS

16th International Conference on Computer Aided Systems Theory
Las Palmas de Gran Canaria, Spain, February 2017

Sixteenth International Conference on
COMPUTER AIDED SYSTEMS THEORY

EUROCAST 2017

Edited by

Alexis Quesada-Arencibia
José Carlos Rodríguez-Rodríguez
Roberto Moreno-Díaz and
Roberto Moreno-Díaz jr.

eurocast 2017

Sixteenth International Conference on Computer Aided Systems Theory

February 19-24, 2017

Museo Elder de la Ciencia y la Tecnología, Las Palmas de Gran Canaria
Canary Islands, Spain

Organized by:

Instituto Universitario de Ciencias y Tecnologías Cibernéticas
Universidad de Las Palmas de Gran Canaria, Spain

Johannes Kepler University Linz
Linz, Austria

Museo Elder de la Ciencia y la Tecnología
Las Palmas de Gran Canaria, Spain

With the collaboration of

Fundación Universitaria de Las Palmas
Österreichische Gesellschaft für Technologie-Politik
Cátedra de Tecnologías Médicas de Gran Canaria
Cabildo Insular de Gran Canaria
Ayuntamiento de Las Palmas de Gran Canaria
Gran Canaria Convention Bureau

Honorary Chairman:
Werner Schimanovich
Austrian Society for Automation and Robotics

Conference Chairs
General: Roberto Moreno-Díaz (Las Palmas)

Program: Franz Pichler (Linz)

Technical: Alexis Quesada-Arencibia (Las Palmas)

Technical Secretariat
Instituto Universitario de Ciencias y Tecnologías Cibernéticas
Universidad de Las Palmas de Gran Canaria
Campus de Tafira
35017 Las Palmas de Gran Canaria, Spain

Phone: +34-928-457108
Fax: +34-928-457099
E-mail: euroccast@iuctc.ulpgc.es

Preface

The concept of CAST as Computer Aided Systems Theory was introduced by Franz Pichler of Linz in the late 80's to name computer theoretical and practical tools for problems in System Science. It was thought as the third component (the other two being CAD and CAM) that will provide for a complete picture of the path from Computer and Systems Sciences to practical developments in Science and Engineering.

Franz Pichler organized in the University of Linz the first CAST workshop in April 1988, which demonstrated the acceptance of the concepts by the scientific and technical community. Next, Roberto Moreno-Díaz, of the University of Las Palmas de Gran Canaria joined Franz Pichler, motivated and encouraged by Werner Schimanovich, of the University of Vienna (present Honorary Chairman of Eurocast), and they organized the first international meeting on CAST, (Las Palmas February 1989), under the name EUROCAST'89 that again proved to be a very successful gathering of systems theorists, computer scientists and engineers from most of European countries, North America and Japan. It was agreed that EUROCAST international conferences would be organized every two years, alternating between Las Palmas de Gran Canaria and a continental Europe location, being later decided to celebrate them in Las Palmas. Thus, successive EUROCAST meetings took place in Krems (1991), Las Palmas (1993), Innsbruck (1995), Las Palmas (1997), Vienna (1999), Las Palmas (2001), (2003), (2005), (2007), (2009), (2011), (2013) and (2015) in addition to an extra-European CAST Conference in Ottawa in 1994. Selected papers from those meetings were published by Springer-Verlag Lecture Notes in Computer Science nos. 410, 585. 763,1030, 1333, 1798, 2178, 2809, 3643, 4739, 5717, 6927, 6928, 8111- 8112, 9520 and in several special issues of “Cybernetics and Systems: an International Journal”. EUROCAST and CAST meetings are definitely consolidated, as it is shown by the number and quality of the contributions over the years.

EUROCAST 2017, to be held in the Elder Museum of Science and Technology of Las Palmas, February 19-24, continues with the approach tested in last Conferences as an International computer related Conference with a true interdisciplinary character. The participants profile is presently extended to include fields which are in the frontiers of Science and Engineering of Computers, of Information and Communication Technologies and the fields of Social and Human Sciences. The best paradigm is the Web, with its associate systems engineering, CAD-CAST tools and professional application products (Apps) for services in the social, public and private domains.

There are different specialized Workshops which, in this occasion, are devoted to: **1**.- Systems Theory and Applications, chaired by Pichler (Linz) and Moreno-Díaz (Las Palmas); **2**.-Pioneers and Landmarks in the Development of Information and Communication Technologies, chaired by Pichler (Linz), Stankovic (Nis), Kreuzer, F. and J. (USA); **3**.- Stochastic Models and Applications to Natural, Social and Technological Systems, chaired by Nobile and Di Crescenzo (Salerno); **5**.- Theory and Applications of Metaheuristic Algorithms, chaired by Affenzeller and Jacak

(Hagenberg) and Raidl (Vienna); **6**.- Embedded Systems Security, chaired by Mayrhofer and Schmitzberger (Linz); **7**.- Model-Based System Design, Verification and Simulation, chaired by Nikodem (Wroclaw), Češka (Brno), Ito (Utsunomiya); **10**.- Systems in Industrial Robotics, Automation and IoT, chaired by Stetter (Munich), Markl (Vienna), Jacob (Kempten); 11.- Applications of Signal Processing Technology, chaired by Huemer (Linz), Zagar (Linz), Lunglmayr (Linz), Haselmayr (Linz); **12**.- Algebraic and Combinatorial Methods in Signal and Pattern Analysis, chaired by Astola (Tampere), Moraga (Dortmund), Stankovic (Nis); **13.-** Computer Vision, Deep Learning and Applications, chaired by Penedo (A Coruña), Radeva (Barcelona); **14**.- Computer and Systems Based Methods and Electronic Technologies in Medicine, chaired by Rozenblit (Tucson), Hagelauer (Linz), Maynar (Las Palmas), Klempous (Wroclaw); **15**.- CyberMedical Systems, chaired by Rudas (Budapest), Kovács (Budapest), Fujita (Iwate); **16**.- Socio-economic and Biological Systems: Formal Models and Computer tools, chaired by Schwaninger (St. Gallen), Schoenenberger (Basel), Tretter (Munich), Cull (Corvallis US), Suárez-Araújo (Las Palmas) and **17**.- Intelligent Transportation Systems and Smart Mobility, chaired by Sánchez-Medina (Las Palmas), Celikoglu (Istanbul), Olaverri-Monreal (Wien), García-Fernández (Madrid), Acosta-Sánchez (La Laguna).

In this Conference, as in prior ones, most of the credits of success are due to the chairpersons of the workshops. They, with the counselling of the International Advisory Committee, selected near 154 extended abstracts for oral presentation at the meeting, which are included in this volume. Specific instructions will be given for the preparation of the Post-Conference Publication, which will contain full papers selected, as in prior EUROCAST's, after the oral presentations. The present volume is divided in Chapters corresponding to the Workshops.

The event has been possible thanks to the efforts of the chairpersons of the Workshops in the diffusion and promotion of the Conference, as well as the selection and organization of all the material. The organizers must express their acknowledgement to all contributors and participants and to the invited speakers, Prof. Christian Müller-Scholer from Hamburg, Prof. Manuel Maynar, from Las Palmas and Prof. Jaakko Astola from Tampere, for their readiness to collaborate. Also to the Director of the Elder Museum of Science and Technology, D. José Gilberto Moreno, to the members of the Museum, and finally, to the Collaborator Institutions and to all those which contribute to the success of the Conference as a pleasant and useful scientific, technical and human event.

Las Palmas de Gran Canaria, February 2017.
The Editors.

Table of Contents

Systems Theory and Applications

Pioneers and Landmarks in the development of Information and Communication Technologies

Stochastic Models and Applications to Natural, Social and Technical Systems

Theory and Applications of Metaheuristic Algorithms

Embedded Systems Security

Model-Based System Design, Verification and Simulation

Systems in Industrial Robotics, Automation and IoT

Applications of Signal Processing Technology

Algebraic and Combinatorial Methods in Signal and Pattern Analysis

Computer Vision, Deep learning and Applications

Computer and Systems Based Methods and Electronic Technologies in Medicine

CyberMedical Systems

Socio-economic and Biological Systems. Formal Models and Computer Tools

Intelligent Transportation Systems and Smart Mobility

Utilization of a web browser for complex heterogeneous parallel computing using multi-core CPU / GPU systems

Marek Woda, Adam Hajduga

Department of Computer Engineering
Wrocław University of Technology
11/17 Janiszewskiego, 50-372 Wrocław, Poland
marek.woda@pwr.edu.pl,adam.hajduga@hotmail.com

Keywords: Heterogeneous parallel computing, HTML5, computing in a web browser, OpenCL/WebCL

Extended abstract

Since the invention of the first microprocessor has passed many years. Technological developments in CPU construction is primarily based on increasing the performance of devices, their miniaturization and the reduction of manufacturing costs. Well known Moore's Law, speaking of doubling the number of transistors on a chip at regular intervals, proved to work well over years. Such a trend, due to the technological constraints cannot be everlasting; right now it is observed as it slows down. Limitations in minimum size of the individual components (transistors) and a total power draw of a system, forced to change the direction of the technological development. Instead of boost the clock of a processor, it was decided to multiply its number in a chip. Thanks to clustering of processor cores in a single chip that utilize fast shared cache memory, we still can observe considerable performance boost.

Another approach, recently propagated, involves the use of special, dedicated computation units (such as Graphics Processing Units) to parallelize the operation. In 2006 new graphics chips with unified stream processors were introduced to the market and started to replace outdated one based on specified pixel shader / vertex units. As a result, one can utilize them for general purpose computation while these units are not engaged in rendering graphics. The approach gained its momentum and was adopted as General Purpose on GPU which finally resulted in the project - an open framework to create kernels and communication interface with devices supporting it. Forged under auspices of Khronos Group, OpenCL met with universal acceptance and became a de facto standard.

Advent of Internet era, and common use powerful, mobile devices, made Khronos Group to come up with industry standards that remediate the problem with diversity of devices / operating systems, dealing with displaying accelerated graphics in a browser and with utilization of potent CPUs/GPUs for general purpose computation. That was the trigger to introduce WebGL and WebCL as a counterparts to well known OpenGL and OpenCL.

The study involves the design and implementation of environmental research, on the basis of which to be drawn appropriate conclusions. The project consists of a desktop application, written in C ++ using frameworks OpenCL and OpenGL, and its mobile counterpart (that can be reached via a web browser), using WebCL and WebGL. Both systems allow for solving an advanced computational problem without the use of external libraries (natively in C++ and JScript), dealing with that problem by means of use of GPGPU (WebCL / OpenCL), and lastly allow for visualization the effects (WebGL / OpenGL).

The authors used known, though computationally complex problem of generating fractals as a test ground for the research. Studies consequently compared the different aspects such as:

- The execution time of the algorithm(s) along with render-time (rendered frames per unit time).
- Dependency between screen resolution and time to generate a fractal,
- Measurement time and system resources utilization during the initialization and release of OpenCL / WebCL context.

The contribution of this paper is to demonstrate the legitimacy of the use of WebCL/OpenCL frameworks and GPGPU capabilities in the process of creating complex applications that are run in a web browser. The aim was to use WebCL framework to test the possibility of using GPGPU techniques in the creation of complex applications running directly in a browser (and its potential performance boost / degradation in comparison to a desktop application developed with use of OpenCL). The choice was dictated by the growing importance of Internet services, and the problem they are facing - time to load and performance penalty introduced by a use of web. No direct comparisons of duo OpenCL/OpenGL vs. WebCL/WebGl were made so far. Authors [1–4] proved that these standards are useful, not only in terms of rendering complex graphics in a browser but also capable to deal with complex computations, but none had tried to make complete comparison in terms of performance, features and interoperability of these standards.

References

1. Aho, E., Kuusilinna, K., Aarnio, T., Pietiinen, J. and Nikara, J., 2012, October. Towards real-time applications in mobile web browsers. In Embedded Systems for Real-time Multimedia (ESTIMedia), 2012 IEEE 10th Symposium on (pp. 57-66). IEEE.
2. Hoetzlein, R.C., 2012. Graphics performance in rich internet applications. IEEE computer graphics and applications, 32(5), pp.98-104.
3. Jeon, W., Brutch, T. and Gibbs, S., 2012, April. WebCL for hardware-accelerated web applications. In TIZEN Developer Conference May (pp. 7-9).
4. Khan, F., Foley-Bourgon, V., Kathrotia, S., Lavoie, E. and Hendren, L., 2014, October. Using javascript and WebCL for numerical computations: A comparative study of native and web technologies. In ACM SIGPLAN Notices (Vol. 50, No. 2, pp. 91-102). ACM.

Cognitive informatics - holistic and part-based computations using set theory and relations

Jan Nikodem

Department of Computer Engineering
Wrocław University of Technology
11/17 Janiszewskiego, 50-372 Wrocław, Poland
jan.nikodem@pwr.edu.pl

Keywords: relational system, parallel computing, distributed system modeling, CUDA technology

Extended abstract

When in the 20th century such scientists as Norbert Wiener, John von Neumann, Warren McCulloch [3, 8] formulated the basis of cybernetics, they tended rather to the conception of the human mind in terms of the functioning in a machine, than to the anthropomorphization of the machine. Following this path, taking into account the legacy of the cybernetics, the idea of computerization of the mind has re-emerging today as cognitive informatics [2, 7].

I would like to talk about a new endeavor in this field - the application of set theory and relations in cognitive informatics which are especially useful in solving holistic problems or global/local activity dilemmas. While we arrange the puzzle, it is easier to find its elements, if we know the whole. Without the whole picture a single action becomes meaningless.

The expansion of the modern scientific method, based both on system theory and computer based numerical verification of the studied phenomena, spanning today these areas of reality, that until recently, have been the subject of vague speculative and pure common sense inquiry. We have more and more evidence [1] that the cells in the brain are not only sensitive to certain stimuli, but reacts in accordance with what at the same time doing other cells.

Based on the state-of-the-art in system theory research [6] I will present associative relations, as an element of relational space, which can define limited bandwidth of information transfer, which can define limited bandwidth of information transfer, high cognitive effort and cumbersome and time-consuming calculation as the main problems the science have to face in real world applications outside the laboratory.

Cognitive modeling is our attempt to dealing with holistic and part-based computations in computer based modeling of technical systems which are complex and distributed. We will present sketches of what we've been doing, and some, selected methods will be discussed on the conference. We will present a results of applications of cognitive modeling in creating adaptive human computer interfaces based on visual communication and image processing based on morphological operations [4]. We argue that, if we understand the principles of visual perception, image processing and learning processes that occur in the human brain, we can use this knowledge to improve human computer interface technology.

The presentation will be a comprehensive digest of empirical fact and theoretical considerations biased toward conclusion that we still on the way towards understand how our brain works [5], and how to model this activity using computers.

References

1. Calvin W.Ch.: How Brains Think: Evolving Intelligence, Then and Now, New York: Basic Books, 1996, ISBN 0-465-07277-1.
2. Dupuy, J.-P.: On the Origins of Cognitive Science: The Mechanization of the Mind, The MIT Press, 2009, ISBN 978-026-251-239-8.
3. Lettvin, J. Y., Maturana, H. R., Mcculloch, W. S., Pitts, W. H.: What the Frog's Eye Tells the Frog's Brain. In: Proceedings of the IRE, 1940.
4. Najman L., Hugues T. eds.: Mathematical Morphology: from theory to applications, ISTE-Wiley, 2010, ISBN: 9781848212152, DOI 10.1002/9781118600788.
5. Seung, S.: Connectome. How the Brain's Wiring Makes Us Who We Are?; Houghton Mifflin Harcourt, 2012, ISBN 978-0-547-50818-4.
6. Skyttner L.: General Systems Theory. Ideas and applications; World Scientific Publishing Company, 2001, ISBN 978-9810241766.
7. Wang Y. at al.: Perspectives on Cognitive Informatics and Cognitive Computing, Int. Journal of Cognitive Informatics and Natural Intelligence, 4(1), 1-29, 2010.
8. Wiener N.: Cybernetics or Control and Communication in the Animal and the Machine, Second Edition, The MIT Press, 1961, ISBN: 9780262230070

Reversed Amdahl's Law in Heterogeneous Parallel Computing Systems

Jarosław Rudy[1] and Wojciech Bożejko[2]

[1] Department of Computer Engineering
Wrocław University of Science and Technology
Wybrzeże Wyspiańskiego 27, 50-370
Wrocław, Poland
e-mail: jaroslaw.rudy@pwr.edu.pl

[2] Department of Control Systems and Mechatronics
Wrocław University of Science and Technology
Wybrzeże Wyspiańskiego 27, 50-370
Wrocław, Poland
e-mail: wojciech.bozejko@pwr.edu.pl

1 Extended abstract

In recent years parallel and distributed computing have become standard techniques for speeding up calculations for a wide various applications, ranging from production planning [1] to cosmology [2]. Such a common usage have resulted in a considerable attention from the scientis around the world. The basic theoretical speedup achievable in such parallel computing systems is governed by Amdahl's law [3], which describes the speedup as the function of the number of computing cores (processors).

Despite its usefulness, Amdahl's law has several drawbacks. It disregards the overhead encountered in real-life parallel systems. More importantlyo, it assumes that all the processors in the system are identical. In other words, it describes a homogeneous parallel system. However, in the present day computations are carried out using more than just a series of identical CPUs. Other possibilities include: Graphics Processing Units (GPUs) with hundreds of cores, vector processing (using technologies like SSE instructions or dedicated devices like Xeon Phi) or distributed computing. Moreover, modern parallel computations systems often combine several of aforementioned devices and techniques. The resulting systems are thus heterogeneous. The advantage of such systems is that they allow to better use the processing power of modern computer systems (*e.g.* virtuall all modern computers can achieve parallelization through the use of SSE instructions. Many also have GPUs capable of performing all-purpose computations). Thus, heterogeneous parallel systems have attracted considerable attention over the last years. Examples include work that uses CPU, GPU and Xeon Phi devices at once [4], several surveys [5] and even simulators [6].

Naturally, increase in popularity of heterogeneous parallel systems resulted in some attempts at extending Amdahl's law for use with such systems ([7] to name one recent example). However, trying to directly apply Amdahl's law to heterogeneous systems is difficult, since we lack the means of expressing one type of core (like CPU cores) with some number of cores of another type (like GPU cores). Moreover, different parallel computing techniques have different granularity: SSE vectorization is fine-grained, while distributed computing is coarse-grained and with CPUs, GPUs and Xeon Phi-like systems somewhere in the middle.

Thus, we propose a reversed take on Amdahl's law. First, we describe the given real-life heterogeneous parallel system by its *configuration* (types and number of cores *etc*). Next, we choose a *reference* configuration (usually a single core machine). Then we execute the same, fixed algorithm on both machines and compare the observed computation times. This yields speedup of the given configuration relative to the reference configuration.

Next, we use the reversed version of Amdahl's law: we express the number of cores using the measured speedup. The resulting number (not necessarily an integer) tells us how many referenced configurations would need to be launched in parallel to equal the given (examined) configuration. This in turn allows to compare various heterogeneous systems (using the same reference configuration) by other means than simple comparison of speedups. This, together with known configurations costs, allows to better approximate computational capabilities of parallel systems.

In the paper we introduce the reversed Amdahl's law and show some of its properties, parameters and accuracy. We then use the law to compare two heterogeneous parallel systems in a computer experiment. One system equipped with 8 CPU cores and one with 12 CPU cores and a GPU device (the CPUs are different for each machine).Moreover, both machines employed SSE instructions to improve the computation time. The comparison was done by implementing parallel algorithms for three simple test problems. The results show that the reversed Amdahl's law can be used to compare heterogeneous parallel systems beyond simple comparison of achieved speedups.

References

1. Bożejko W., Uchroński M., Wodecki M., Multi-GPU Tabu Search Metaheuristic for the Flexible Job Shop Scheduling Problem, Advanced Methods and Applications in Computational Intelligence, pp. 43–60 (2014)
2. Meng C., Wang L., Cao Z.,Feng L., Zhu W., Large-scale parallelization based on CPU and GPU cluster for cosmological fluid simulation, Computers & Fluids, vol. 110, pp. 152–158 (2015)
3. Amdahl, G. M.: Validity of the Single Processor Approach to Achieving Large Scale Computing Capabilities, Proceedings of the April 18-20, 1967, Spring Joint Computer Conference, pp. 483–485, Atlantic City, New Jersey (1967)
4. Vialle S., Contassot-Vivier S.: Algorithmic scheme for hybrid computing with CPU, Xeon-Phi/MIC and GPU devices on a single machine, International Conference on Parallel Computing 2015
5. Mittal S., Vetter J. S.: A Survey of CPU-GPU Heterogeneous Computing Techniques, ACM Computing Surveys, vol. 47 (4), pp. 1–35 (2015)
6. Power J., Hestness J., Orr M. S., Hill M. D., Wood D.A., gem5-gpu: A Heterogeneous CPU-GPU Simulator, IEEE Computer Architecture Letters, vol. 14 (1), pp. 34–36 (2015)
7. Pei S., Kim M. S., Gaudiot J. L.: Extending Amdahl's Law for Heterogeneous Multicore Processor with Consideration of the Overhead of Data Preparation, IEEE Embedded Systems Letters, vol. 8 (1), pp. 26–29 (2016)

A Comparative Study for Real-Time Streaming Protocols Implementations

Iván Santos-González[1], Jezabel Molina-Gil[1], Alexandra Rivero-García[1], Héctor Reboso Morales[1] and Rafael Álvarez Sánchez[2]

[1] Departamento de Ingeniería Informática y de Sistemas, Universidad de La Laguna, 38271 La Laguna, Tenerife, España
[2] Departamento de Ciencia de la Computación e Inteligencia Artificial, Universidad de Alicante, Alicante, España
(jsantosg, jmmolina, ariverog, hreboso)@ull.edu.es, ralvarez@dccia.ua.es

1 Extended Abstract

The airports security and protection model involves using different resources to secure its infrastructure. The most used are; equipment for the inspection of persons and luggage, closed circuit television cameras throughout the airport, anti-intrusion systems and, detection and recording systems. However, all these resources imply a high cost that not all airports can afford.

Currently, there are new proposals for security which propose the use of mobile technology as video surveillance system. Mobile technology provide performance, portability, transmission capacity and the ability to capture videos and images that do it possible, and even more important, it reduces costs.

Sharing information among nodes in a network can be done in different ways. The kind of the information that the system shares usually determines the method for the chosen communication. In this proposal, sharing audio and video media is the main objective. For this reason, the most important point is the guarantee of a low latency, low jitter and efficient transmissions, but occasional losses could be tolerated. The media streaming protocol is defined taking into account the structure of the packets and the algorithms used to send real-time media on a network.

There are several protocols, which allow the implementation of video surveillance system in mobile phones. In particular, WebRTC and RTCP, are the most used. This work focuses on carrying out a study of three possible implementations in order to analyze their weaknesses, strengths and conclude which one would be the most suitable to be use on mobile devices. This proposal evaluates times at live streaming with the use of smartphones. It takes into account the establishment time and stream reception time from a single source, to a large quantity of receivers. In order to perform the analysis three Android applications have been implemented, a web service and two different multimedia services. The study includes the implementation of three different proposals that claims to be the innovaty solutions in videostreaming.

The first proposal that is analyzed, uses the Real Time Streaming Protocol (RTSP) [3] based on Real-time Transport Protocol (RTP) [4] with a multimedia server that acts as intermediary between the two devices that do the streaming. It is a non-connection oriented application layer protocol that uses a session associated to an identifier. RTSP usually uses the UDP protocol to share the video and audio data and TCP for the control (TCP is used just if it is necessary).

The second proposal implements Web Real-Time Communications (WebRTC) protocol with a multimedia server that acts as intermediary too. WebRTC [1] is a project maintained by Google based on RTP. This system allows real-time communications through some Application Programming Interfaces (API) with a high quality, low latency and low bandwidth consumption.

The last proposal is based on WebRTC and STUN (Session Traversal Utilities for NAT) and it does not use any multimedia server. The STUN server allows clients to find out their public address, the type of NAT they are behind and the Internet side port associated by the NAT with a particular local port. This information is used to set up UDP communication between the client and the VoIP provider to establish a call. The STUN protocol is defined in RFC 3489 [2].

In particular, this paper present a comparative study of three different systems designed to evaluate times at live streaming, using Android smartphones. Simulations analyse the time requirements for establishing and sending packets in a videostreaming connection in each one of the proposed solutions. The results show a 20% of performance improvement of WebRTC protocol over RTSP. However, the last analysed protocols based on STUN and without using a multimedia server, provides an improvement of 38% respect to WebRTC and 49% respect to RTSP. Hence, the obtained results show that the last proposals offer significant improvements over previous schemes.

Acknowledgments

Research partially supported by TESIS2015010102, TESIS2015010106, RTC-2014-1648-8, TEC2014-54110-R, MTM-2015-69138-REDT and DIG02-INSITU.

References

1. Bergkvist, A., Burnett, D., Jennings, C.: A. narayanan," webrtc 1.0: Real-time communication between browsers. World Wide Web Consortium WD WD-webrtc-20120821 (2012)
2. Rosenberg, J., Weinberger, J., Huitema, C., Mahy, R.: Rfc 3489. STUN, IETF, March (2003)
3. Schulzrinne, H.: Real time streaming protocol (rtsp) (1998)
4. Schulzrinne, H., Casner, S., Frederick, R., Jacobson, V.: Real-time transport protocol. RFC1899 (2003)

Linear models for the modified self-shrinking generator ⋆

Sara D. Cardell[1] and Amparo Fúster-Sabater[2]

[1] Instituto de Matemática, Estatística e Computação Científica, R. Sérgio Buarque de Holanda, 651, UNICAMP, 13083-859, Campinas, Brazil
sdcardell@ime.unicamp.br
[2] Instituto de Tecnologías Físicas y de la Información, CSIC, 144, Serrano, 28006, Madrid, Spain
amparo@iec.csic.es

Secret-key encryption functions are usually divided into two separated classes: stream ciphers and block-ciphers depending on whether the encryption function is applied either to each individual bit or to a block of bits of the original message, respectively. Stream ciphers try to imitate the one-time pad cipher or Vernam cipher [4] that remains as the only absolutely unbreakable cipher. They are designed to generate from a short key a long sequence (the keystream sequence) of pseudorandom bits.

The **modified self-shrinking generator** (MSSG), a decimation-based keystream sequence generator, was introduced by Kanso in [2] as an improved version of the self-shrinking generator [3]. In the MSSG case, the m-sequence $\{u_i\}$ generated by a maximal-length LFSR is self-decimated. The decimation rule is very simple: given $\{u_{2i}, u_{2i+1}, u_{2i+2}\}$, $i = 0, 1, 2, \ldots$, three consecutive bits of the m-sequence $\{u_i\}$, the output sequence $\{s_j\}$ is computed as

$$\begin{cases} \text{If } u_{2i} + u_{2i+1} = 1 \text{ then } s_j = u_{2i+2}, \\ \text{If } u_{2i} + u_{2i+1} = 0 \text{ then } u_{2i+2} \text{ is discarded.} \end{cases}$$

We call the output sequence $\{s_j\}$ as the **modified self-shrunken sequence** (MSS-sequence). If the length of the LFSR that generates $\{u_i\}$ is denoted by L, then the linear complexity $\mathcal{LC}$ of the corresponding MSS-sequence satisfies: $2^{\lfloor \frac{L}{3} \rfloor - 1} \leq \mathcal{LC} \leq 2^{L-1} - (L-2)$, and the period T of such a sequence, when L is odd, satisfies: $2^{\lfloor \frac{L}{3} \rfloor} \leq T \leq 2^{L-1}$ as proved in [2]. As usual, the key of this generator is the initial state of the register that generates $\{u_i\}$.

In [1], the authors showed that the MSS-sequence can be obtained through linear cellular automata. A **cellular automaton** (CA) is a discrete device where the contents of a cell at instant t are updated following a *rule* or function that involves k neighbour cells at instant $(t-1)$ [5]. If the operations involved in such

⋆ The first author was supported by FAPESP with number of process 2015/07246-0. The second author was supported by Ministerio de Economía y Competitividad, Spain under grant grant TIN2014-55325-C2-1-R (ProCriCiS) and Comunidad de Madrid, Spain, under grant S2013/ICE-3095-CM (CIBERDINE). Both authors also want to thank Feder Funds.

a rule are composed exclusively by XOR operations, then the CA is said to be linear.

A linear CA can be also seen as a linear transformation, where each state $\boldsymbol{x}^{t+1}$ is obtained from the previous state $\boldsymbol{x}^t$. Considering the CAs in [1], this linear transformation has the following form:

$$\begin{aligned} T : \mathbb{F}_2^l \ &\longrightarrow \mathbb{F}_2^l \\ \boldsymbol{x}^t = (x_0^t, x_1^t, \ldots, x_{l-1}^t) &\longrightarrow \boldsymbol{x}^{t+1} = T(\boldsymbol{x}^t) = \boldsymbol{x}^t A \\ &\qquad\quad = (x_0^t + x_1^t, x_1^t + x_2^t, \ldots, x_{l-2}^t + x_{l-1}^t, x_{l-1}^t), \end{aligned}$$

where the transition matrix, A, is an $l \times l$ matrix with ones in both the main diagonal and the subdiagonal and zero elsewhere.

On the other hand, let E be the one-sided shift operator that acts on the terms of a sequence, for example, $Ea_n = a_{n+1}$ and $E^k a_n = a_{n+k}$. We claim that the MSS-sequence $\{s_j\}$ based on the m-sequence $\{u_i\}$ is a particular solution of the homogeneous linear difference equation

$$(E+1)^{2^{L-1}} z_n = 0,$$

whose characteristic polynomial is $(1+x)^{2^{L-1}}$.

Decimation was introduced in order to break the linearity of the m-sequences generated by LFSRs. However, in this work we see that the MSS-sequence can be modelled as the output sequence of two different linear structures: one based on linear CA and the other one based on linear difference equations. The previous statement implies that MSS-sequences are sensitive to suffer a cryptanalysis that takes advantage of their linearity.

References

1. Cardell, S. D., Fúster-Sabater, A.: Recovering the MSS-sequence via CA. Procedia Computer Science. 80, 599–606 (2016).
2. Kanso, A.: Modified self-shrinking generator. Procedia Computer Science. 80, 599–606 (2016). Computers and Electrical Engineering. 36(1):993–1001 (2010).
3. Meier, W., Staffelbach, O.:The self-shrinking generator. In: Advances in Cryptology, EUROCRYPT 1994. LNCS. 950, 205–214. Springer-Verlag (1994).
4. Nagaraj, N.: One-Time Pad as a nonlinear dynamical system. Commun Nonlinear Sci Numer Simulat. 17, 4029–4036 (2012).
5. Wolfram, S.: Cellular automata as simple self-organizing system. Caltrech preprint CALT. 68–938 (1982).

A Survey of the Latest Results in Networked Systems Achieved at CzechTech

Michael Šebek, Kristian Hengster-Movric, Dan Martinec, Ivo Herman, Stefan Knotek and Zdeněk Hurák⋆

Faculty of Electrical Engineering and Czech Institute of Informatics, Robotics and Cybernetics, Czech Technical University in Prague, Czech Republic
michael.sebek@fel.cvut.cz, www.dce.fel.cvut.cz

Abstract. The paper surveys recent theoretical results of the CzechTech group in network systems. Several problems are scanned such as the local dynamics impact; the role of Laplacian matrix properties; waves and transfer functions in networks.Also, several simulation and experiments examples are presented from different such as platoons of automated vehicles for future automated highway systems, nonlinear oscillators synchronization for Smart Grids and vibration suppression through networks in new materials for future cars and airplanes.

Keywords: Networked systems, Laplacian matrix, decentralized control, collaborative control, consensus, synchronization, waves, transfer functions, platooning, smart grids, and suppression of vibrations.

Nowadays, the world is all interconnected. Everything affects everything else. All kinds of systems are interconnected in different networks at many levels of the hierarchy. This networked nature becomes pervasive and past centralized approaches fail to describe, understand, and control current industrial, communication, social and many other hypercomplex systems. That is why entirely new decentralized and collaborative methods and architectures are to be developed for control, decision and many other purposes and goals to design and handle highly autonomous, heterogeneous and hybrid networked subsystems.

Quite naturally, networked systems have long been part of the mainstream in systems and control research, development, and applications. Many research groups are pursuing the topic at the CzechTech. This article aims to provide a brief overview of recent achievements of this group in theory and practice of network systems. Also, it demonstrates how the initial curiosity-driven research can give rise to experimental, development and application effort and results.

In the paper, several topics will be enlightened including:

- The effect of various feedback types within the network [5, 6].
- How local dynamics impacts stability, performance, and scaling [4, 7].
- Laplacian matrix properties in system analysis and design [2, 3].
- Dense or sparse network? Tight or loose binding?

⋆ The work was partly supported by the Czech Ministry of Education project LG15049.

– Waves in networks: propagation, bouncing and absorption [1].
– Transfer functions within the network.

Fig. 1. The EU Sartre project: a platoon of Volvo driver-less cars in normal traffic. Successful Control system design by CzechTech graduates in Ricardo Prague company.

During the survey, several simulation, experimental and application examples from different engineering fields will be demonstrated and exploited such as

– Automated highway systems - platoons of automated vehicles.
– Smart Grids - nonlinear synchronization of oscillators.
– New materials for future cars and airplanes - vibrations suppression.

References

1. Wave-absorbing vehicular platoon controller. European Journal of Control 20, 237–248 (July 2014)
2. Nonzero bound on fiedler eigenvalue causes exponential growth of h-infinity norm of vehicular platoon. IEEE Transactions on Automatic Control 60, 2248 – 2253 (August 2015)
3. Transients of platoons with asymmetric and different laplacians. Systems & Control Letters 91, 28–35 (May 2016)
4. Scaling in bidirectional platoons with dynamic controllers and proportional asymmetry. IEEE Transactions on Automatic Control 99, 1–7 (In Press)
5. Hengster-Movric, K., Lewis, F.L., Sebek, M.: Distributed static output-feedback control for state synchronization in networks of identical lti systems. Automatica 53, 282 – 290 (03/2015 2015)
6. Hengster-Movric, K., Lewis, F.L., Šebek, M., Vyhlídal, T.: Cooperative synchronization control for agents with control delays: A synchronizing region approach. Journal of the Franklin Institute 352, 2002 – 2028 (05/2015 2015)
7. Martinec, D., Herman, I., Šebek, M.: On the necessity of symmetric positional coupling for string stability. IEEE Transactions on Control of Network Systems PP, 1–10 (In Press)

Conditional Dispersion in Multi-split Decision Trees

Monica J. Ruiz-Miró and Margaret Miró-Julià[1]

Departament de Ciències Matemàtiques i Informàtica
Universitat de les Illes Balears
07122 Palma de Mallorca, SPAIN[1]
moferru@gmail.com, margaret.miro@uib.es[1]

Extended abstract

Data Mining emerges in response to technological advances and considers the treatment of large amounts of information locked up in databases. The objective of Data Mining is the extraction of new, valid, comprehensible and useful knowledge by the construction of models that seek structural patterns in the data, to ultimately make predictions on future data. The challenge of extracting knowledge from data is an interdisciplinary discipline and draws upon research in statistics, pattern recognition and machine learning among others. Clustering and classification are two methods used in data mining.

Clustering is a common technique for identifying natural groups hidden in data. Clustering is a process that automatically discovers structure in data and does not require any supervision, it is an unsupervised learning method [1]. The grouping is done in such a way that objects in the same group or cluster are more similar to each other than to those in other clusters. It is important to use the appropriate similarity metric to measure the proximity between two objects, but the separability of clusters must also be taken into account. The goal is to find clusterings that satisfy homogeneity within each cluster as well as heterogeneity between clusters [2].

The problem of comparing two or more sets of overlapping data as the foundation for identifying different partitions of quantitative data was addressed in [3]. A method for cluster analysis and statistical based split of the data was presented. The clusters are formed using similarity measures based on boxplots. Boxplots are non-parametric, they display variation in the data of a statistical population without making any assumptions of the underlying statistical distribution. The spacings between the different parts of the box indicate the degree of dispersion and skewness in the data, and also show outliers. A boxplot is a convenient way to graphically display the data and identify outliers. Boxplots are useful when comparing data sets. Therefore, boxplots are a convenient tool to study overlapping data. Once clusters are identified the multiway split selection is forthcoming. The number of splits depends on the number of clusters found.

Classification is a process of categorization, where objects are recognized, differentiated and understood using the training set of data. Classification is a supervised learning technique where a training set and correctly classified observations are available. In order to predict the class labels of a new object, hidden relationships between attributes are discovered. There are many classification techniques available. One of them is the decision tree model. A decision tree is a structure that includes a root node, branches, and leaf nodes. Each internal node denotes a test on an attribute, each branch denotes the outcome of the test, and each leaf node holds a class label. The topmost node in the tree is the root node. Decision tree learning creates a decision tree from the training set, that can be used as a predictive model which maps observations about a new object, represented in the branches, to conclusions about the object's class label, represented in the leaves. In data mining, a decision tree describes data and can be used to classify new objects.

The majority of methods and techniques used to construct decision trees are binary based. These algorithms decide the split for binary class values that allows for the optimal decision tree. This is convenient when the class is dichotomous. This paper addresses the problem of constructing decision trees where the multi-split values assigned to the branches are found using statistical concepts that measure the distance between partitions and allow for the formation of clusters. In particular, quartiles and interquartilic range are used in the calculation of a dissimilarity measure between clusters. The attribute selection is carried out using discriminant analysis procedures. Given a database with p numerical attributes X_i and a class or variable of interest Y which takes class values $y_n = 1, 2, \ldots, c$, a simple, precise and interpretable tree (predictive model) is built using the DMT (Decision Multi-split Tree) method.

The DMT method builds a decision tree considering multi-splits or multiway splits. A multiway split partitions the database in Z subgroups, $z \geq 2$. In addition to considering multi-splits, the DMT method studies where to carry out the multi-split in such a way as to get the most homogeneous possible subgroups. The behavior of the data will be studied through the dispersion of the p attributes. Actually we are not interested in the dispersion of the attribute X_i but the dispersion for each class value of the attribute X_i. That is, the dispersion conditioned by the class value for each attribute X_i. The purpose of the DMT method is finding possible clusters of classes with similar dispersion in each attribute and calculating the interval or cutting points to separate these clusters of the most discriminatory way possible.

References

1. Cios, K. J. and Pedrycz, W. and Swiniarski, R. W. and Kurgan, L. A.: Data Mining. A Knowledge Discovery Approach, Springer, New York, 2007.
2. Grabmeier, J. and Rudolph, A.: Techniques of Cluster Algorithms in Data Mining. Data Mining and Knowledge Discovery, **6**, 2002, 303–360.
3. Miró-Ruiz, M.J. and Miró-Julià, M.: Similarity and Distance Measures Based on Quantiles. Computer Aided Systems Theory - EUROCAST 2015, LNCS **9520**, 2015, 80–87.

Extension of open data model

Cestmir Halbich[1], Vaclav Vostrovsky[2], Jan Tyrychtr[1]

[1]Department of Information Technologies, PEF, Czech University of Life Sciences Prague, Kamycka 129, 165 21 Prague 6 – Suchdol
[2]Department of Information Engineering, PEF, Czech University of Life Sciences Prague, Kamycka 129, 165 21 Prague 6 – Suchdol

halbich@pef.czu.cz

Keywords: Open data model, correctness, conceptual model, logical model, physical model

Extended abstract

The main purpose of using open data (further OD) is to provide content. From the definition of OD they incorporate two important attributes: machine readable format and use without any legal restriction. The issue of the so called "Open data" has recently been investigated and discussed in detail. However, it is only possible to benefit from OD if the data are true, or correct. There are plenty of models of OD and their metrics, the presented model extends one of its quality attributes - correctness. This model prefers to use this aggregated attribute rather than individual attributes of quality. The main aim of this paper is to define, using the given model, the possibilities of monitoring the spread of varroa bee through OD. Its additional aim is to propose an acceptable procedure of use of such data as relevant information support in solving problems associated with the spread of varroa bee. Our innovative solution of monitoring the spread of varroa bee is based on databases. The presented methodology draws on a mental model of implementation, rather than conceptual and relational model, involving physical model and finally testing and validation. We use data resulting from laboratory analysis available at all district offices of the Regional Veterinary Administration and local Czech Beekeepers Association.

OD can become a relevant source of information readily available on the Internet, not only in the public sector but also the commercial sector [1]. However, if the data from this laboratory analysis are to meet such potential they need to be of certain quality. In general, the quality is defined by international standards (SQuaRE) in the established quality model. To meet objectives of this paper techniques and procedures of the relational database technology will be used. The presented solution will be demonstrated and subsequently verified by means of OD relating to varroa bee. Other methods include the methods of the relational database technology, in particular methods of data integrity. Pivotal in this procedure are the following issues: authentication, anonymization, integration and aggregation. Very important feature in this procedure is the anonymity of these OD. The procedure involves practical use of the resultant data in strategic and tactical decisions by beekeepers. As an example we can use the solution to the following dilemma: The beekeeper decides whether it is appropriate to start keeping bees on a larger scale in the village of Opočno. A solution to this problem can be found using the given SQL statement:

```
SELECT Vill,NumbvarDistr,AvervarDistr,NumbPlague, NumbNosema FROM
risk_of_beekeeping WHERE Vill='Opočno';
Vill       NumbvarDistr    AvervarDistr    NumbPlague     NumbNosema
Opočno        24                45              0        strong incidence
```

The obtained data can be transformed into the following recommendations: In the monitored area it is not appropriate to operate a beekeeping business on a larger scale. This area is determined by a higher level of infection of bees, which can be the cause of lower efficiency of this activity. Current OD can be used more effectively during the decision making processes. The key indicators can be analysed from different points of view of aggregation (the numbers or averages for districts, for regions, years etc.). The results and knowledge included herein have been obtained owing to support from the Internal grant agency of the FEM, Czech University of Life Sciences in Prague, IGA č. 20161008 – "The potential of open data in the agricultural sector with regard to their correctness and aggregation. "

References.

1. Vostrovský, V., Tyrychtr, J. and Ulman, M. 2015, 'Potential of Open Data in the Agricultural eGovernment', *AGRIS on-line Papers in Economics and Informatics*, vol. 7, no. 2, pp. 103-113, ISSN 1804-1930

2. Kučera, J., Chlapek, D. Benefits and Risks of Open Government Data. Journal of Systems Integration. 2014, Vol. 5, No. 1, p. 30-41. ISSN 1804-2724.

Dynamical Feedforward Control of Three-Tank System

Pavol Bisták

Slovak University of Technology in Bratislava
Ilkovičova 3, 812 19 Bratislava, Slovakia
Pavol.Bistak@stuba.sk,
WWW: http://uamt.fei.stuba.sk *

Abstract. This paper deals with a new approach to the control design for a third-order nonlinear plant with time-delays. Starting from a pole-assignment proportional-derivative controller for the triple-integrator plant generalized for a constrained control and equiped by a gain scheduling to respect the nonlinear plant dynamics, its structure is used for a dynamical feedforward control that is extended by a nonlinear disturbance observer taking into account filtration of noisy signals and the non-modelled time-delays always present in control circuits. By using an example of a three-tank liquid level control in a hydraulic plant, performance of the resulting two-degree-of-freedom model reference control of nonlinear time-delayed systems with an integral action will be evaluated by standard criterions.

Keywords: dynamical feedforward, model reference control, input constraints, nonlinear system, time-delay, nonlinear disturbance observer

1 Summary

Although the today's control theory offers numerous sophisticated control approaches that are suitable for complex control tasks, especially in applications to simple control loops one may still find new solutions improving significantly the control performance [3]. Since such simple plants represent a high percentage of all practical applications [1], there still exists a potential for a new research. Especially when considering nonlinear systems we are used to deal with different linearization techniques to deploy linear control system design (the exact linearization method based on a differential geometry [4], e.g.). However, the effect of the nonlinear dynamics typically occurs only at sufficiently rapid transitions appearing under sufficiently strong control actions leading to another typically nonlinear issue - to a control signal saturation. Furthermore, the rapid changes exhibit effect of a nonmodelled dynamics. Its identification and consideration requires usually approaches different from the identification and control design

* This work has been partially supported by the grants VEGA 1/0937/14 and APVV-0343-12 .

approaches dealing with the dominant dynamics. Thus, for a succesfull design of nonlinear control loop it is usually not enough to focuss on a single traditional method built on a rigorous mathematical framework, but one needs a modular approach integrating several such approaches, each of them specialized in a closer set of problems to be solved.

The proposed work is built on integration of several basic approaches to cover all main issues of a control design: consideration of the control constraints that exhibit the nonlinear plant dynamics and use of the disturbance observer based PI and PID control [3] offering an increased robustness that is finally extended by the two-degree-of-freedom model reference control. The paper will firstly review a constrained PD controller design for a nonlinear system transformed under a modified exact linearization to a triple integrator [2]. This primary control loop will be later considered as a ”master” producing an ideal control input, as well as an ideal plant output for the model reference control structure. It fulfills the task of a dynamical feedforward control that is later governed by the second control loop ensuring the plant stabilization and compensation of the model imperfections. The established two-degree-of-freedom model reference control structure is finally completed by an integral action produced by a nonlinear disturbance observer with an inverse plant dynamics (Fig. 1). At the end the influence of the allways present non-modelled time-delays is evaluated.

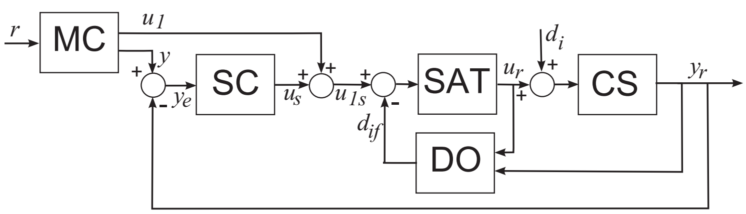


Fig. 1. Model reference control block diagram - model control (MC), stabilizing controller (SC), saturation (SAT), disturbance observer (DO), controlled system (CS)

References

1. Åström, K. J. and Hägglund, T.: Revisiting the Ziegler-Nichols step response method for PID control. J. Process Control, 14, 635-650, (2004)
2. Bisták, P.: Time sub-optimal control of triple integrator applied to real three-tank hydraulic system. In: LNCS: Proceedings of 15th International Conference on Computer Aided Systems Theory. Las Palmas de Gran Canaria; Spain. Springer Verlag, Vol. 9520, pp. 25-32, (2015)
3. Huba, M.: Comparing 2DOF PI and Predictive Disturbance Observer Based Filtered PI Control. Journal of Process Control, Vol. 23, 10, pp. 1379–1400, (2013)
4. Isidori, A.: Nonlinear Control Systems. 3rd edition, Springer Verlag, New York, (1995)

A Computer Vision System for Classifying and Counting Lego Pieces

A.J. Rodríguez-Garrido, A. Quesada-Arencibia, J.C. Rodríguez-Rodríguez, C.R. García, R. Moreno-Díaz jr

Institute for Cybernetic Science and Technology
University of Las Palmas de Gran Canaria
alberto.rodriguez.garrido@gmail.com, jcarlos@iuctc.ulpgc.es, {alexis.quesada, ruben.garcia, roberto.morenodiaz}@ulpgc.es

Extended abstract

We introduce a prototype of an artificial vision system that leads to a first step for automating the classification and counting of Lego kits from the MindStorm series. For an human operator, it is a slow, tedious task that can be misleading because of the repetitive nature of the activity and the high number of pieces and the similarities between them. This necessity appeared during the logistic preparations of Ciberlandia Educational Project [1] workshops. These activities include a robot-building phase that requires the perfect inventory of the materials. Consequently, the frequency of the inventories is determined by the schedule of workshops, which can be daily, or even more often.

The prototype consists of the following modules:

• Image acquisition module. It takes or captures images containing Lego pieces in a background and light-controlled environment. There are some requirements for the scenes. The objects to be treated are Lego pieces. There must be no occlusion between pieces. Pieces must not be in contact with each other. There must be an appropriate contrast between the background and pieces.

• Detection and segmentation module. Preprocessing, detection, segmentation and normalization of captured images. During the image preprocessing, color conversion, equalization, morphological and threshold operations have been used in order to adapt these images to the requirements of the detection and segmentation phases. During the detection and segmentation phase, the Watershed segmentation algorithm [2] was used. Due to its impact regarding performance terms in the classification and counting module, a standardization process was added. That is, all abstracted pieces must have the same size and maintain their original aspect.

• Classification and counting module. As many Support Vector Machines (SVM) [3] as categories of the kit were used. An innovative aspect is the procedure used to obtain the feature vectors that feed the SVM. Two approaches were used:

― a 'Naïve' approach, proposed by the authors, in which the feature vector is obtained from a cluster. This approach offers greater simplicity and shorter training and classification time, as shown by the results.

– a standard approach, using the Bag of Words (BOW) model [4]. Utilizing a word dictionary enables greater normalization of the results, as well as less redundancy in the training data.

In both approaches, and due to the need for invariability against rotations (pieces are scattered), Dense SIFT, SURF Dense, SURF and Hu's Moments image descriptors were used. Additionally, KAZE [5] and 'AKAZE' [6] binary descriptors were also used, which required the implementation of a binary clustering technique.

Regarding the counting phase, from each classifier by category is immediate.

The objective of the prototype is to lay the groundwork for the future classification and counting tool for Lego pieces. In order to do so, a wide battery of combination methods (procedure used to obtain the feature vector, image descriptor) and configuration tests (cluster size, type of SVM nucleus) were made. The purpose was to measure its reliability, this is, the number of correctly identified pieces, as well as time costs associated with the training and classification stages.

Regarding this aspect, a maximum success rate of 98% was obtained with the BOW approach configuration, cluster size of 500 and KAZE binary image descriptor.

As it was expected, the "Naïve" approach obtained an average of 31,25% and 25,04%, lower rates comparing the BOW approach in training and classification times.

It is observed that, in spite of its simplicity, the average reliability of the 'Naïve' approach is 3,74% lower comparing to the 'BOW' approach.

Regarding our main contributions, it is necessary to emphasize the 'Naïve' approach, as it contributes to use, improve and disseminate the new KAZE and AKAZE binary image descriptors, the implementation and use of a binary clustering technique and the set of tests itself.

As a future work, it is aimed to make the system tolerant to the physical contacts between pieces in the scene, to introduce color as an element of classification, and to explore new, not considered classification paradigms.

References

1. J. C. Rodríguez Rodríguez, M.-P. Eduardo, V. Jorge Padrón, J. Alemán Alemán, C. R. García and A. Quesada-Arencibia, "Ciberlandia: An Educational Robotics Program to Promote STEM Careers in Primary and Secondary Schools," in Interactive Collaborative Learning, vol. 1, Las Palmas de Gran Canaria, 2017, pp. 440-454.
2. F. Meyer, "Color image segmentation. In Image Processing and its Applications," in International Conference, 1992.
3. C. Chih-Chung and L. Chih-Jen, "LIBSVM: A Library for Support Vector Machines," ACM Transactions on Intelligent Systems and Technology (TIST), vol. 2, no. 3, 2011.
4. G. Csurka, C. R. Dance, L. Fan, J. Willamowski and C. Bray, "Visual Categorization with Bags of Keypoints," in European Conference on Computer Vision (ECCV), Prague, 2004.
5. P. F. Alcantarilla, A. Bartoli and A. Davison, "Kaze Features," in European Conference in Computer Vision, Fiorenze, 2012.
6. P. F. Alcantarilla, J. Nuevo and A. Bartoli, "Fast Explicit Diffusion for Accelerated Features in Nonlinear Scale Spaces," in British Machine Vision Conference (BMVC), Bristol, 2013.

Stenographic Data Heritage Preservation Using Sharing Images App

Zenon Chaczko[1] , Raniyah Wazirali[2], Lucia Carrion Gordon[3] and Wojciech Bozejko[4]

University of technology, Sydney Australia, Sydney1,2,3
Institute of Computer Engineering, Control and Robotics [4]
Zenon.Chaczko@uts.edu.au[1], Lucia.CarrionGordon@uts.edu.au[2]
Raniyah.wazirali@uts.edu.au[3] , Wojciech.Bozejko@pwr.wroc.pl[4]

Abstract. With the advent of smartphones, we have the ability to take a photo and upload it to the internet whenever we desire. Hence, it may be of key importance to include metadata of the image for heritage preservation. This project focuses on heritage concepts and their importance in every evolving and changing digital domain where system solutions have to be sustainable, sharable, efficient and suitable to the basic user needs. Steganography provides a feasible and viable solution to ensure secure heritage preservation of the multimedia content. By embedding information directly into the image, the information about the image will never be lost, as it is not separated from its original source. The aim of the paper is to demonstrate this aspect via an image sharing app that allows users to exchange messages and personalized information that is embedded in the image such that it is inaccessible without knowing their keys.

Keywords: Steganography, Digital Heritage Preservation, Ontology, Image Sharing

1 Introduction

Creating images and uploading them has become easy with the introduction of smart phones. Basic metadata of an image could be considered unsuitable for the purpose of personal information due to its easy access through websites and other applications that can extract metadata from an image. The heritage term is defining as the crucial and central part of the research; we can refer it to 'heritage is those items and places that are valued by the community and is conserved and preserved for future generations [1]. The data is often in isolation. However, the data needs to be with the connections and relationships. It gives the meaning of the information. If that heritage is not preserved, the information can be lost forever. The aim of this research paper demonstrates how steganography can be used for embedding critical data into the image that is readable via a dedicated visualization tools [2], [3].

2 An Overview of Stenographic Sharing

The development of the preservation model is related with the value of information. Steganography is the practice of concealing information within another piece of information. This information can later be retrieved by someone with the right key. The most common way of hiding information within images is by selecting an area using a key provided by the user, and then changing the least significant bits of the color of the pixels

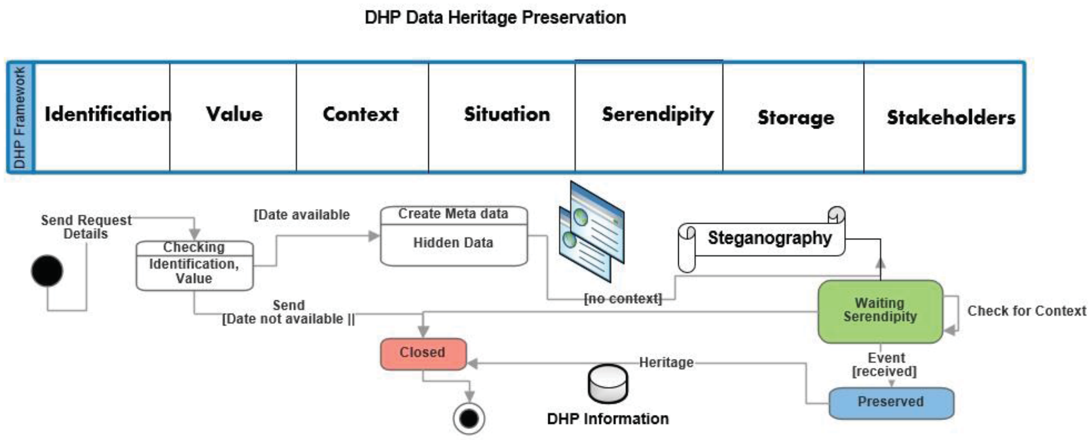


Figure 1: SDHP Workflow Model

in that area to that of the bits of information the user wants to hide. This method is undetectable to the naked eye, and can be difficult to discover even programmatically.
The images produced by the Photo App will have messages embedded in them, so it's somewhat irrelevant in the context of an image sharing app. Human cultural heritage, documents and artifacts increase regularly and place Data Management as a crucial issue. Figure 1 shows the Steganographic Data Heritage Preservation (SDHP) workflow model. The first stage involves exploration and approaches based on review of recent advances. The second stage involves adaptation of architectural framework and development of software system architecture in order to build the system prototype. Increasing regulatory compliance mandates are forcing enterprises to seek new approaches to managing reference data. The approach of tracking reference data in spreadsheets and doing manual reconciliation can be time consuming and error prone. As various organizations merge and businesses evolve, reference data must be continually mapped and merged as applications are linked and integrated, accuracy and consistency, realize improved data quality, strategy lets organizations adapt reference data as the business evolves. It is important to highlight the type and structure of data. Through the time preserving digital information has a process for designing a practical system for managing massive amounts of critical data. The way to improve the understanding of the methodology, the information has to consider two dimensions: access dimension and cognitive dimension. Both of them have the level of importance in terms of the results. As a methodology of treatment digital preservation, it could be risky even when the strategy could develop a clear idea of digital resources and digital artifacts. Steganography is a powerful and effective multimedia tool for the Digital Heritage Preservation. This can be clearly shown in the presented case study of a successful implementation of steganography technique in the Photo App that allows editing photos, adding messages and uploading the gallery for viewing, exchanging messages and searching for images by other users.

References

[1] UNESCO, "Information Document Glossary of World Heritage Terms (June, 1996)." http://whc.unesco.org/archive/gloss96.htm.
[2] R. R. Wazirali, Z. Chaczko, and A. Kale, "Digital Multimedia Archiving Based on Optimization Steganography System" Asia-Pacific Conference on Computer Aided System Engineering (APCASE). IEEE, 2014
[3] N. F. Johnson and S. Jajodia, Exploring steganography: Seeing the unseen, Computer, vol. 31, no. 2, pp. 26A ¸S34, 1998.

An Automatic and Human Assisted Stereoscopic Rectification Method for Practical Film Production Environments

Roman Dudek, Carmelo Cuenca, and Francisca Quintana

Universidad de Las Palmas de Gran Canaria,
Juan de Quesada 30, 35001 Las Palmas de Gran Canaria, Spain
romandudek@gmail.com,carmelo.cuenca@ulpgc.es,francisca.quintana@ulpgc.es
http://www.ulpgc.es/

Abstract. We propose, test and deploy a production grade system for the alignment of film scenes shot using a stereoscopic pair of film cameras. To guarantee that every scene can be aligned, the system offers a hierarchy of approaches: Fully automatic optical flow based alignment method, Semi automatic computer assisted method and finally an intuitive manual method. Different visualization methods are explored to assist the alignment quality control, and allow interactive correction if automatic results were unsatisfactory.

Keywords: stereoscopy, rectification, alignment, interactive, application, optical flow, GUI

1 Summary

While stereoscopic movies were shot as early as 1910 [1], they always were considered a specialty until the James Cameron's Avatar movie was released in 2009. Many other high level productions followed the lead, thus arising a need for stereoscopic tools for professional film post-production. The work described in this article was researched and developed for such a software tool.

Films shot natively for 3D use a rig consisting of a stereoscopic pair of professional film cameras, mounted in either parallel or mirror configuration. The camera pair and their lenses are mechanically aligned. However there is a limit to the precision of the alignment, thus requiring further image alignment in the post-production stage to avoid viewer discomfort.

Many works on stereoscopic alignment have been published, so the mathematical model is already developed and it can be found in works like [2]. The stereoscopic alignment methods eventually result in a 3x3 matrix describing the homography relation between the image pair [3], allowing the image pair to be rectified. However, if the automated process fails for a difficult image pair, it would be very hard to align the images manually, as the numbers forming the matrix have no obvious user interpretation in terms like "scale" or "rotation".

As a different approximation, in this work we describe the homography transformation by a set of human intuitive parameters: Scale, Rotation, Offset, Keysotne and Shear. Then, we use an iterative Optical Flow based algorithm to calculate these parameters. After that we define the homography matrix combining the matrices corresponding to the above mentioned parameters, in the order of application as usual in 3D modeling software, for better user understanding:

$$H = H_{keystone} * H_{shear} * H_{rotate} * H_{scale} * H_{offset} \tag{1}$$

In case the automated result is not satisfactory, the user can manually select reference points with certain properties to fix individual parameters. For example, two points on an approximately vertical line could be chosen to define the scale rectification. Optical Flow would be still used to calculate the actual feature match at these points. If the Optical Flow fails even at these well chosen points, the system allows to manually match the image features and derive the values of individual parameters of the homography.

As an example of our results, compare figures 1 and 2 to see the geometric alignment of the scenes. Each image is a checkerboard combination of the left and right view, making any difference easy to spot on the square boundaries. Observe that before the alignment almost all objects are both horizontally and vertically unaligned, seen as jagged edges on the checkerboard square boundaries. After the geometry alignment, the only jagged edges are observable on the near seagulls wings, due to their inter-ocular parallax.

Fig. 1. Non-rectified sample.

Fig. 2. Rectified sample.

References

1. B. Mendiburu. 3d Movie Making: Stereoscopic Digital Cinema from Script to Screen. Focal Press/Elsevier, (2009)
2. A. Fusiello, L. Irsara. Quasi-Euclidean uncalibrated epipolar rectification. ICPR, pags. 14, (2008)
3. R. Hartley, A. Zisserman. Multiple View Geometry in Computer Vision. Cambridge University Press, New York, NY, USA, 2 edition, (2003).

Secure UAV-Based System to Detect and Filter Sea Objects using Image Processing

Moisés Lodeiro-Santiago[1], Cándido Caballero-Gil[1], Ricardo Aguasca-Colomo[2], Jorge Munilla-Fajardo[3], and Jorge Ramió-Aguirre[4]

[1] Departamento de Ingeniería Informática y de Sistemas, Universidad de La Laguna, Tenerife. Spain (mlodeirs, ccabgil)@ull.edu.es
[2] Instituto Universitario SIANI, Universidad de Las Palmas de Gran Canaria, Gran Canaria. Spain ricardo.aguasca@ulpgc.es
[3] Departamento de Ingeniería de Comunicaciones, Universidad de Málaga, Málaga. Spain munilla@ic.uma.es
[4] Departamento de Sistemas Informáticos, Universidad Politécnica de Madrid, Madrid. Spain jramio@eui.upm.es

Keywords: UAV, Image Processing, Patera, Ship Detection, Security

Extended Abstract

This paper offers a novel solution to face one of the most controversial issues in the world in the last years: immigration. More than four million of Syrians have been forced to flee their country since the Bashar al-Assad regime began in 2011 [1]. Between 2015 and 2016 more than 850.000 people sought refuge in Europe [2], and most of them (220.000 approximately) crossed the frontiers illegally across the Mediterranean, according to the European External Borders Agency, Frontex [3]. Apart of Syria's conflict, a lot of people from Africa each day tries to cross the frontier to look for a better life in the Canary Islands or in the mainland [4] [5]. The most used method to try to reach the Canary Islands coast is with large fishing boats (known as pateras). The number of migrations using boats increases each year in comparison with the number of people that cross the frontiers walking [6]. Throughout the years many ship detection proposals have been presented based on the use of image processing combined with different strategies such as multiscale techniques [7], photogrammetric analysis of images acquired by UAV [8], fuzzy logic [9], optical satellite images [10], etc. These works show different situations where image processing and drones or Unmanned Aerial Vehicles (UAVs) can be helpful to detect small ships by combining different technologies. In order to propose a solution to the problem, here we define a new system that combines real-time image processing to detect patterns in sea, and UAVs. On the one hand, image processing is a methodology based on some open libraries of Artificial Intelligence and Mathematics to apply various filters to images, OpenCV and Numpy. On the other hand, UAVs are aircraft vehicles controlled either remotely by pilots or autonomously by on-board computers. The image processing libraries are used for the management of images and the application of filters to acquire a final matrix that represents some possible pateras in the image. Besides, the described system is combined with a real-time marine traffic database that let us know the actual GPS positions of registered ships. The developed system has been designed to filter unregistered objects, based on the object size estimated using trigonometric operations on the altitude and drone's camera meta-data like focal and camera angle. After applying various OpenCV filters and discarding small-sized objects to each frame, we can get a detection rate of match of real pateras of 84% in the worst case and 100% in the best case. In comparison with other systems, we use the image processing process in a computer to take advantage of the computing capacity instead of using the smartphone's CPU. Also, as aforementioned, in order to discard false-positive cases we use a ship GPS position database to compare all the GPS positions of registered ships in the area, with the GPS position given by the drone after a detection of a suspicious ship. The drone takes pictures each 3 seconds and sends it using a three-way security channel. The first security level applied in our system is provided by the LTE connection that uses the SNOW 3G algorithm for the integrity protection and stream cipher of the UMTS technology [11]. The second one is given by the secure HTTPs server's connection. Finally, the third one is a pre-shared AES256 CBC key to encrypt the communications between the drone and the server.

References

1. "Syrian refugees: four million people forced to flee as crisis deepens." https://www.theguardian.com/global-development/2015/jul/09/syria-refugees-4-million-people-flee-crisis-deepens.
2. "The un refugee agency." http://www.unhcr.org/.
3. "European border and coast guard agency." http://www.frontex.europa.eu/.
4. D. Wastl-Walter *et al.*, *Borders, Fences and Walls: State of Insecurity?* Ashgate Publishing, Ltd., 2014.
5. "Migratory routes map." http://frontex.europa.eu/trends-and-routes/migratory-routes-map/.
6. P. Soddu, "Ceuta and melilla: Security, human rights and frontier control,"
7. M. Tello, C. Lpez-Martnez, J. Mallorqu, T. Tares, and H. Greidanus, "Advances in unsupervised ship detection with multiscale techniques," vol. 4, pp. IV979–IV982, 2009. cited By 2.
8. M. Díaz-Cabrera, J. Cabrera-Gámez, R. Aguasca-Colomo, and K. Miatliuk, *Photogrammetric Analysis of Images Acquired by an UAV*, pp. 109–116. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013.
9. G. Margarit and A. Tabasco, "Ship classification in single-pol sar images based on fuzzy logic," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 8, pp. 3129–3138, 2011. cited By 27.
10. G. Huang, Y. Wang, Y. Zhang, and Y. Tian, "Ship detection using texture statistics from optical satellite images," pp. 507–512, 2011. cited By 2.
11. I. Santos-Gonzlez, A. Rivero-Garca, P. Caballero-Gil, and C. Hernndez-Goya, "Alternative communication system for emergency situations," vol. 2, pp. 397–402, 2014. cited By 0.

Competitions as a Vehicle to Strengthen Learning Experience

Stefan Hoermann, Matthias Friedrichsen

Aalen University, Beethovenstraße 1, 73430 Aalen, Germany

Abstract. In this paper, we discuss the educational benefit of student competitions in the area of mobile robotic systems. Specifically, we can confirm an educational benefit of competitions for self-driving cars with simplified environmental requirements in conjunction with constraints.

Keywords: Mobile robot systems, self-driving cars, machine vision, education

1 Motivation

There are numerous examples of products available where mobile robot systems step into our private live. Robot vacuum cleaners and lawn mowers were the first devices of this class entering our domestic homes. As a next step our passenger vehicles will be equipped to drive autonomous. Almost all car manufacturers provide at least electronic assistance systems that can be understood as a starting point towards self-driving car technology. If this is not enough, researchers are working on the next generation of robot systems making our life more easy and comfortable. The range of systems reach from mail delivery systems [2] to robotic systems supporting us doing the laundry [1] and housekeeping.

Is this new technology ready to be used in large scale? Partially yes, however, there is more effort required to be carried out to improve current robotic systems. Just think about thousands of vacuum robots wandering in random patterns through our living rooms. Luckily, the robot vacuum cleaner navigation problem seems to be solved. But, are self-driving cars already smart enough to take over the steering wheel in all situations? The number of job advertisements in the area of mobile robot systems answer this question: Young engineers are wanted for further development.

2 Application Example

The goal of robotic competition events is to motivate young students and researcher to work in the area of mobile robot systems. In the area of self-driving cars there are several competitions available. Two of these are the Carolo Cup [3] and the Audi Autonomous Driving Cup [4], where self-driving cars in 1:10 scale need to solve realistic driving maneuvers. However, the environment in these competitions is being kept very simple with, e.g. white road markings on black floor. In comparison to this, the famous Formula Student engineering design competition starts with the new driverless discipline in 2017 [5] where more realistic situations may be solved.

In this paper the educational benefit of simplified environmental requirements in self-driving car competitions is being analyzed. The detection and recognition of simple road markings as they are defined in the rules of the Carolo Cup competition will be taken as an example application. As educational benefit the possibility of application of basic algorithms and requirement of adaptation of these algorithms to meet certain conditions will be the measure. The first will provide a low entry level by just applying knowledge, while the latter creates deeper understanding by transforming algorithms.

3 Results and Future Work

At Aalen University, there is a team of students preparing their car for the Carolo Cup competition. Three dynamic disciplines have to be solved: following the course of the road with and without obstacles and parallel parking.

The team could achieve the detection and recognition of the ideal road markings with white tape on black ground with a set of basic algorithms. In this step the transfer of the lecture was the application and combination of image processing and numeric algorithms. Existing implementations were be used to keep the entry level low. However, the first implementation required too much computational power, which is typically not available on lightweight competition cars. In a second step the algorithms were individually optimized to meet the computational power of a Raspberry Pi computer. This step requires and boosts a deep understanding of the algorithms. The Carolo Cup competition motivated the team to take this hurdle.

We can show, that a competition setup with simplified environment in the area of self-driving cars provide a very good learning scenario. The beginning is motivating due to low entry level, but constraints require further engineering of basic algorithms.

A comparison between experiences of the Aalen Carolo Cup and Formula Student Driverless teams will provide more evidence.

References

1. Christian Bersch and Benjamin Pitzer and Sören Kammel, Bimanual robotic cloth manipulation for laundry folding in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2011, pages 1413 – 1419
2. Self-Driving Robots Will Soon Deliver The Mail In Switzerland, http://www.forbes.com/sites/federicoguerrini/2016/08/26/will-automation-spell-the-end-of-the-mailman-delivery-robots-soon-to-appear-on-swiss-streets/#3bcf858d17b1 [verified 30.10.2016]
3. Carolo Cup, https://wiki.ifr.ing.tu-bs.de/carolocup/news, [verified 30.10.2016]
4. Audi Autonomous Driving Cup, https://www.audi-autonomous-driving-cup.com/ [verified 30.10.2016]
5. Formula Student Driverless, https://www.formulastudent.de/press-pr/news/news-details/article/autonomous-driving-at-formula-student-germany-2017/, [verified 30.10.2016]

Modifications of Model Free Control to FOTD Plants

Mikuláš Huba and Tomáš Huba

Slovak University of Technology in Bratislava
Ilkovičova 3, 812 19 Bratislava, Slovakia
mikulas.huba, tomas.huba@stuba.sk,
WWW: http://uamt.fei.stuba.sk

Abstract. Model free control (MFC) represents one of possible alternatives to traditional approaches as PID control, disturbance observer based control (DOBC), internal model control (IMC), etc. As one of its central features one could mention use of finite-impulse-response (FIR) filters in input disturbance reconstruction. The paper deals with characterizing links of MFC to these approaches and proposing simple procedures for tuning of such controllers for the plants approximated by the first order time delayed models.

Keywords: Model free control, PID control, disturbance observer based control, internal model control

1 Summary

Model free control (MFC) [1] offering as its product "intelligent" PID control represents one of popular alternatives to such approaches as PID control [2], disturbance observer based control (DOBC) [3], internal model control (IMC) [4], advanced disturbance rejection control (ADRC) [5–8].

Based on mathematically complex approaches of functional analysis and differential algebra it has been formulated within the so called flatness-based control. In order to bring the complex theory as close as possible to practice, proposed intelligent PID controllers offer great simplicity for their application and tuning. The simplest solution, the intelligent proportional (iP) "model free" controller [1] is based on an "ultra local" integral model written usually as

$$\dot{y} = F + \alpha u \tag{1}$$

Thereby, $\alpha \in \mathbb{R}$ is considered to be (in general) a non-physical constant parameter that may be interpreted as a gain with an estimate $\overline{\alpha}$. F is representing an equivalent disturbance acting on the integrator input. It is approximated by a piecewise constant parameter ϕ that may be determined from measured $\dot{y}_m$ as

$$\phi = \dot{y}_m - \overline{\alpha} u \tag{2}$$

In calculating a mean value of this parameter by its integration over a time interval L, the integration may be accomplished by a transfer function $Q_c(s) =$

$(1 - e^{-sL})/(Ls)$. However, since it is just marginally stable, it is preferably accomplished in a discrete-time form by a FIR filter

$$Q_d(z) = \frac{1}{N}\sum_{1}^{N} z^{-i}\ ;\ \ N = IP(\frac{L}{T_s}) \tag{3}$$

where $T_s < L$ is the sampling period, z^{-1} the shift operator and IP represents an integer part.

Let us specify a required output reference trajectory by $y^*,\ \dot{y}^*$ and the tracking error trajectory as $e = y - y^*,\ \dot{e} = \dot{y} - \dot{y}^*$. The iP control algorithm may finally be written in the form

$$u = \frac{\dot{y}^* - \overline{K}_P e - \phi}{\overline{\alpha}} \tag{4}$$

where $\overline{K}_P$ is a chosen proportional gain.

It will be shown in the paper that the reference trajectory y^*, the controller gain $\overline{K}_P$ and the length of the FIR filter N (together with the sampling period T_s) play the key roles in implementation of the iP control. Simple recommendations for their choice based on the integral plus dead time (IPDT) and first order time delayed (FOTD) plant models will be given.

Together with other alternatives, the iP controller will be represented in an integrating context and it will be explained, why such a solutions may not be based on an output disturbance reconstruction and compensation.

An experimental comparison in a real time control of a noisy nonlinear thermal system will be given.

References

1. M. Fliess and C. Join, "Model-free control," *International Journal of Control*, vol. 86, no. 12, pp. 2228–2252, 2013.
2. K. J. Åström and T. Hägglund, *Advanced PID Control.* NC: ISA, Research Triangle Park, 2006.
3. E. Schrijver and J. van Dijk, "Disturbance observers for rigid mechanical systems: Equivalence, stability, and design," *ASME, J. Dyn. Sys., Meas., Control*, vol. 124 (4), pp. 539–548, 2002.
4. M. Morari and E. Zafiriou, *Robust Process Control.* Englewood Cliffs, N. Jersey: Prentice Hall, 1989.
5. J. Han, "From PID to Active Disturbance Rejection Control," *Industrial Electronics, IEEE Transactions on*, vol. 56, no. 3, pp. 900 –906, march 2009.
6. Z. Gao, "Active disturbance rejection control: a paradigm shift in feedback control system design," in *American Control Conference, 2006*, 2006, pp. 2399–2405.
7. Z. Gao, "On the centrality of disturbance rejection in automatic control," *ISA Trans.*, 2013.
8. R. Madoński and P. Herman, "Survey on methods of increasing the efficiency of extended state disturbance observers," *ISA transactions*, vol. 56, pp. 18–27, 2015.

PIRX^{3D} – Pilotless reconfigurable experimental UAV

Jens Altenburg, Christopher Hilgert, Johannes von Eichel-Streiber

University of Applied Science, Bingen am Rhein, Germany
j.altenburg@th-bingen.de, c.hilgert@th-bingen.de,
j.voneichelstreiber@th-bingen.de

Abstract. The combination of smart control algorithms, miniaturized avionics and optimized 3D printing technology is the base of a powerful UAV. The mechanical construction of the sensor, payload and driving module allows an ideal adjustment to different mission scenarios. Using a test environment of a flight simulator and an external motion platform allows testing of PID control algorithms in the laboratory under realistic conditions. The implementation of the results is carried out on an ARM Cortex-M3 microcontroller. Within the UAV, the data are exchanged under hard real-time conditions on the Futaba SBUS.2 bus system. All mechanical modules have their own control processor. For an ideal adaptation to the aerodynamics, components of the airframe will be manufactured by 3D printers.

Keywords: UAV, Flight Simulator, PID, 3D-Printer, Hardware-in-the-loop, ARM Cortex M3, Direct Memory Access (DMA), Futaba SBUS.2, Realtime Operation System, cooperative Multitasking

1 Preface

Radio controlled aircrafts or unmanned aerial vehicles have a long history, especially in military. They were equipped with high precision electro-mechanical autopilots. With nowadays components, i.e. MEMS, microcontrollers and high performance brushless motors, it should be possible to design better (at least equal) and much cheaper control systems, shouldn't it?

The UAV consists of three electronic blocks, the on-board computer, the payload computer and the drive control. The onboard computer is the central part of the on-board electronics. Situational awareness, the flight control algorithms and the telemetry are concentrated in it.

As long as no (flying) hardware exists, no real sensor values are given. Without data, no algorithms can be validated and tested. A flight simulator for model aircrafts will be very helpful.

To get data as real as possible, the simulated data stream is not used as a direct input to the flight controller. The simulator has been expanded with an external moving platform. Controlled by two servos, two gyro axes can be moved simultaneously by the simulated model aircraft on the PC. In fact, it is not a piece of reality, but not so

far away from it. In the first step it is possible to reduce the complexness of the onboard computer by using only four input sources: flight course, flying altitude, lateral control and pitch axis. Every input channel has its own PID controller.
Issues of transport and set-up time play an important role for the practical use. Therefore the airframe is constructed of three mechanical parts. The sensor module contains the on-board computer, including the position detectors, the barometer, the pitot tube, GPS, telemetry and remote control receiver as well as the optional radar equipment.
The inclusion of 3D printers in the prototype was not initially provided. It was not until after the first (successful) test flights loomed the limits of the use of foam materials, that the step has ventured to redesign.

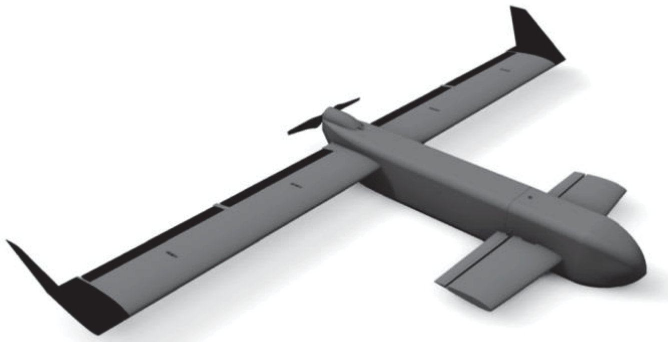


Fig. 1. The first prototype of the UAV PIRX^{3D} manufactured from 3D printed parts

2 Literature

[1] Altenburg, J.; "AONE - A highly sophisticated test bench for Flight Control Systems", Scientific Reports - 21st International Scientific Conference Mittweida (October 26-27 2011) ISSN 1437-7624, Nr. 4, 2011

[2] http://www.futabarc.com/sbus/index.html

[3] von Eichel-Streiber, Johannes: “Entwicklung und Inbetriebnahme einer eingebetteten Mehrachs-Regelung zur Flugstabilisierung eines UAV“, Master Thesis, TH Bingen 2016

[4] Hilgert, Christopher: “Entwurf und Realisierung eines Bordcomputers für ein UAV”, Bachelor Thesis, FH Bingen 2014

[5] Hilgert, Christopher:“Spezifizierung und Analyse von Radarsensoren zur Nutzung in unbemannten Flugsystemen“, Master Thesis, TH Bingen 2016

[7] Stüwe,Botho: „Peenemünde-West - Die Erprobungsstelle der Luftwaffe", Bechtle Verlag Esslingen, Seite 504 ff.

[8] Franke, Hans-Martini: „Flugregler-Systeme" Oldenburg Verlag München Wien, 1968

[9] Altenburg, J.; "INES – Intelligentes Elektroniksystem für Flugdrohnen", Scientific Reports - 23st International Scientific Conference Mittweida (October 05-06 2014) ISSN 1437-7624, Nr. 3, 2014

The Models that Can Be Matched by Feedback

Vladimír Kučera

Czech Institute of Informatics, Robotics and Cybernetics,
Czech Technical University, Prague, Czech Republic
vladimir.kucera@cvut.cz

Model matching (or exact model matching) is a problem of great interest in systems theory and applications [1]. It consists of compensating a given system so as to achieve a specified target transfer function matrix.

More specifically, given a linear, time-invariant system (A, B, C, D) with n states, m inputs, and p outputs described by the equations

$$\dot{x}(t) = Ax(t) + Bu(t),\ y(t) = Cx(t) + Du(t)$$

that give rise to the $p \times m$ transfer function matrix

$$T(s) = C(sI - A)^{-1} B + D,$$

we seek to determine a static state feedback law (F, G) of the form

$$u(t) = Fx(t) + Gv(t)$$

with r external inputs such that the closed-loop transfer function matrix

$$T_{F,G}(s) = (C + DF)(sI - A - BF)^{-1} BG + DG$$

equals a specified, $p \times r$ proper rational matrix $T_m(s)$.

The problem is difficult to solve in full generality. In case $r = m$ and G is square and nonsingular the state feedback law is said to be regular and the problem greatly simplifies [2].

The solvability conditions in the general, nonregular case are obtained as follows. Let $N_s(s)$, $D(s)$ be right coprime polynomial matrices such that

$$(sI - A)^{-1} B = N_s(s) D^{-1}(s)$$

and $D(s)$ is column reduced with column degrees d_1, d_2, ..., d_m. Denote

$$N(s) := CN_s(s) + DD(s),$$

so that

$$T(s) = N(s) D^{-1}(s).$$

Let $N_m(s)$, $D_m(s)$ be right coprime polynomial matrices such that

$$T_m(s) = N_m(s)D_m^{-1}(s).$$

Theorem 1. [3]. There exists a solution of the model matching problem via static state feedback if and only if

(a) the equation

$$N(s)U(s) = N_m(s)V(s)$$

admits a polynomial matrix solution pair $U(s)$, $V(s)$ such that $V(s)$ is $r \times r$ and nonsingular;

(b) there exist a polynomial matrix $H(s)$ and a constant matrix Z, where $H(s)$ is $m \times m$ and nonsingular, column reduced and with column degrees d_1, d_2, ..., d_m, such that

$$H^{-1}(s)Z = U(s)\left[D_m(s)V(s)\right]^{-1}. \qquad \square$$

The conditions are rather implicit. It is therefore of interest to explicitly and more efficiently characterize the models that can be matched by compensating a given system, that is to say, to describe the set of the closed-loop transfer function matrices $T_{F,G}(s)$ obtainable by feedback.

Theorem 2. The set of model transfer function matrices that can be matched to a given system by feedback is given by

$$T_m(s) = N(s)\left[D(s)+Q(s)\right]^{-1} G$$

where $Q(s)$ is any $m \times m$ polynomial matrix such that $Q(s)D^{-1}(s)$ is strictly proper, G is any real matrix of size $m \times r$, and r is any positive integer. $\square$

The proof is based on the fact [4] that the set X of m-row polynomial vectors $w(s)$ such that $w(s)D^{-1}(s)$ is strictly proper, is a real vector space of dimension $d := d_1 + d_2 + ... + d_m$, and the rows of $N_s(s)$ form a basis for X.

Acknowledgment

This work was supported by the Technology Agency of the Czech Republic under Project TE01020197 Center for Applied Cybernetics.

References

1. Kučera, V., Castañeda Toledo, E.: A review of stable exact model matching by state feedback. In: *Proc. 22nd Mediterranean Conference on Control and Automation*, Palermo, 2014, pp. 85-90.
2. Wolovich, W.A.: The use of state feedback for exact model matching. *SIAM J. Contr.* 10, 512-523 (1972).
3. Kučera, V.: Model matching by non-regular static state feedback. In: *Proc. American Control Conference*, Chicago, 2015, pp. 3528-3533.
4. Hautus, M.L.J., Heymann, M.: Linear feedback – An algebraic approach. *SIAM J. Contr. Optimiz.* 16, 83-105 (1978).

An Underwater Gripper with Integrated Force/Torque Sensor for Robotic Manipulation and Cooperation

G. Palli, L. Moriello, U. Scarcia and C. Melchiorri

DEI - Università di Bologna, Viale Risorgimento 2, Bologna, Italy

Abstract. In this paper, a robotic gripper designed for the Italian project MARIS is presented. The gripper is characterized by modular actuation, cable-based transmission and a force/torque sensor integrated in the wrist interface. The wrist force/torque sensor is based on optoelectronic technology for reducing the cost, simplify the electronics and allowing a simple integration with the other part of the system.

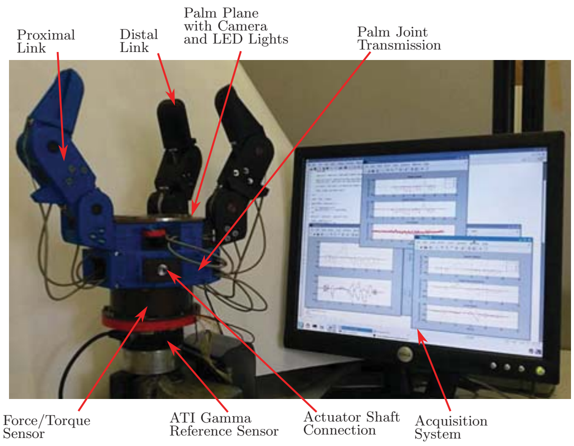
This gripper has been mounted on the 7-dof manipulator of the MARIS robot and used for underwater manipulation activities. In particular, the force/torque sensor is necessary for allowing the collaboration between multiple robots, as foreseen within the MARIS project activities.

1 Design of the MARIS Gripper

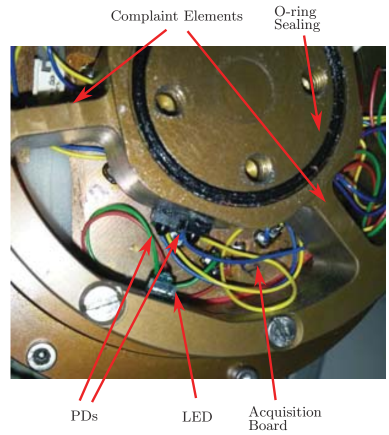
The gripper designed for the Italian project MARIS [2], shown in Fig. 1(a), can operate at a depth of 50 m and can grasp cylindrical objects with diameter from 5 to 200 mm. Both precision, parallel and power grasps can be performed. The gripper is equipped with irreversible actuators to allow maintaining the grasp without consuming any power, and transmission system compliance is provided to adapt to object shape irregularities and uncertain dimensions. Moreover, the gripper is equipped with a wrist force/torque sensor, as shown in detail in Fig. 1(b). This gripper represent the evolution of previous devices developed by the same authors for previous research projects [1,5]. It has three fingers: one opposable thumb, and two identical fingers (named right and left finger respectively). The thumb has two links only: the proximal link, connected to the palm by a revolute joint (proximal joint) with a rotational axes parallel to the palm plane, and a distal link connected to the proximal link by a revolute joint (distal joint) whose rotational axes is also parallel to the palm plane. The right and left fingers differ from the thumb by the connection of the finger to the palm: in this case, an additional joint (palm joint) with rotational axis perpendicular to the palm plane is introduced between the palm and the proximal link, allowing the rotation of the whole finger with respect to the palm perpendicular axis. This arrangement allows performing both parallel grasps as well as precision grasps, by means of opposition of the fingertips.

The gripper has 8 joints, each one driven by an independent closed-loop cable actuation. On the basis of an analysis of the required gripper capabilities, and in order to reduce the overall weight, only 3 (identical) motors are used for the actuation. Obviously, couplings among the joints is present: these couplings are implemented in a very simple way by connecting in parallel the cable driving system of the three joint groups (i.e. distal, proximal and palm joints) to the same motor.

The finger phalanges are manufactured in ABS plastic for reducing the weight and increasing the buoyancy, whereas anodized aluminum has been adopted for the structural parts, such as the wrist flange and the palm structure. The gripper weight is about 4.5 daN in air, and about 1 daN in water. The gripper is also provided

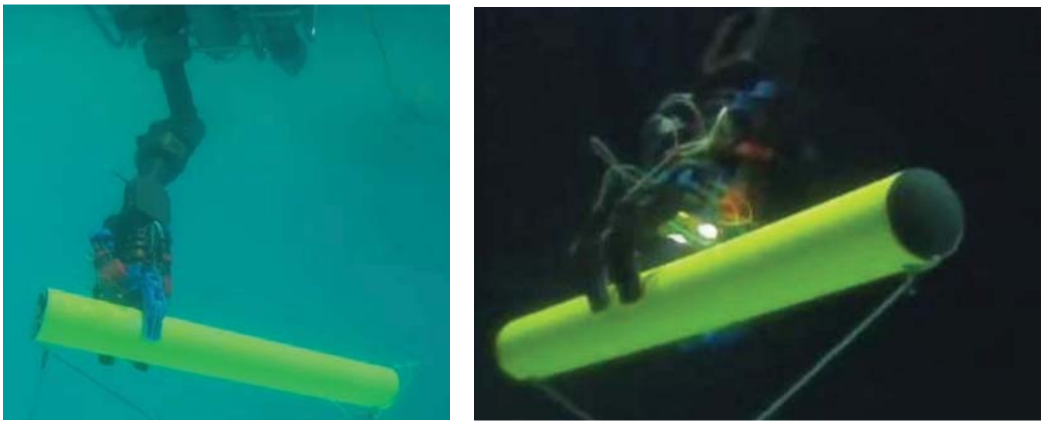


(a) The gripper mounted on the reference sensor during wrist force/torque sensor calibration.



(b) Detailed view of the wrist force/torque interior.

Fig. 1. Detailed view of the gripper and of the wrist force/torque sensor.



(a) (b)

Fig. 2. The MARIS UVMS during grasping operations in the underwater environment.

with a camera with a resolution of 1024x768 pixel and 30 fps. Moreover, a couple of high-power LED capable of 3000 lumens each have been integrated in the gripper palm to allow proper camera operation in the underwater environment.

The gripper has been designed with a modular actuation approach, and is driven by three electric motors, the Faulhaber EN 2250 BX4 CCD brushless DC motor with integrated motion controller and CAN interface, capable of continuous power of 12 W and provided with a 14:1 gearbox, guaranteeing a maximum torque of 1 Nm in continuous operation and of 1.54 Nm in intermittent operation. An additional worm gear 20:1 speed reducer is connected to the motor output shaft in order to obtain a proper torque/speed ratio between the motor and the load axis together with a more suitable arrangement of the motor for reducing the actuation encumbrance. The actuator housing is designed to allows replacing the motor very rapidly in case of fault. Moreover, a reduction ratio of 2.6:1 is achieved by means of the different radii of the driving and the joint pulleys adopted in the cable transmission. Considering a 20% torque loss due to friction along the cable transmission, the maximum normal force applicable by each finger in continuous operation is about 150 N, which can be considered satisfactory for the typical operations of the MARIS project.

The wrist force/torque sensor is implemented by means of optoelectronic components, and its working principle is based on the modulation of the current flowing through a PhotoDetector (PD) as a consequence of the variation of the relative position of a infrared light source (LED), and in particular of the angle of view between the optoelectronic components and the length of the optical path, the reader can refer to [3, 4] for a complete analysis of the system. The sensor allows detecting the deformation of the gripper wrist mechanical structure caused by the contact with the grasped objects or the environment, allowing the estimation of both the forces and the torques applied to the gripper.

The gripper has been mounted on the 7-dof manipulator the MARIS Underwater Vehicle Manipulator Systems (UVMS) is provided with and has been successfully used during autonomous grasping and transportation experiments, as show in Fig. 2.

References

1. Bemfica, J., Melchiorri, C., Moriello, L., Palli, G., Scarcia, U.: A three-fingered cable-driven gripper for underwater applications. In: Proc. IEEE Int. Conf. on Robotics and Automation. pp. 2469–2474 (May 2014)
2. Casalino, G., Caccia, M., Caselli, S., Melchiorri, C., Antonelli, G., Caiti, A., Indiveri, G., Cannata, G., Simetti, E., Torelli, S., Sperind, A., Wanderlingh, F., Muscolo, G., Bibuli, M., Bruzzone, G., Zereik, E., Odetti, A., Spirandelli, E., Ranieri, A., Aleotti, J., Rizzini, D., Oleari, F., Kallasi, F., Palli, G., Scarcia, U., Moriello, L., Cataldi, E.: Underwater intervention robotics: An outline of the Italian national project Maris. Marine Technology Society Journal 50(4), 98–107 (2016)
3. Palli, G., Moriello, L., Scarcia, U., Melchiorri, C.: Development of an optoelectronic 6-axis force/torque sensor for robotic applications. Sensors and Actuators A: Physical 220(0), 333–346 (2014)
4. Palli, G., Pirozzi, S.: Force sensor based on discrete optoelectronic components and compliant frames. Sensors and Actuators A: Physical 165, 239–249 (2011)
5. Ribas, D., Ridao, P., Turetta, A., Melchiorri, C., Palli, G., Fernandez, J., Sanz, P.: I-AUV Mechatronics Integration for the TRIDENT FP7 Project. IEEE/ASME Trans. on Mechatronics 20(5), 2583–2592 (2015)

Konrad Zuse's first computing devices

Roland Vollmar

Karlsruhe Institute of Technology
Institute of Theoretical Informatics
D-76131 Karlsruhe
vollmar@ira.uka.de

After a short introduction to the history of mechanical computing the principles of Konrad Zuses (1910–1995) developments of the so-called Z1–Z4 will be discussed.

Before the emerging of Zuse's devices the (electro-)mechanical calculators operated with gear wheels, sprocket wheels or step rolls on the decimal base. As an employee of an aircraft company Konrad Zuse was bored by simple statical calculations. Therefore in 1935 he began his considerations for automatic processing of the forms and at last he developed another type of calculator based on the dual system with floating point numbers. The arithmetical unit and the storage unit (with 64 words) of the Z1 were ingeniously built by metal plates with cutouts (realized by hand with a jigsaw) which were arranged in several layers and moved by vertical rods. The data were input as decimal numbers on a console and the program by a punch tape. In principle the functioning was given but with a very limited reliability. Nevertheless the soundness of the concept was proved.

For his second machine (Z2) Zuse used electromechanical relais for the arithmetical unit but still a mechanical storage unit.

Of overwhelming interest is the Z3, the "first fully automatic program controlled and freely programmable in a binary floating point working computing device" (F.L. Bauer in [4][1]) which Konrad Zuse completed in 1941. The following quotation [6] underlines the significance of this machine: "... the Z3 was the first machine in the world that could be said to be a fully working calculator with automatic control of its operations."

During the war it has been destroyed by the bombing of Berlin.

The next machine Zuse built (Z4) had a relay arithmical unit but again a mechanical storage because a realization with relays resulted in an inadequate size and weight. He brought essential parts of the Z4 on an adventurous flight through Germany in the last weeks of the war into the Allgäu where he completed it. It was rented to the ETH Zürich and worked there quite reliable during several years.

The influence of Z22, a computer built in the company he founded, on the establishing of Informatics at German universities will be described.

Zuse's construction of control computer devices and his early idea of an array computer will only be mentioned.

At last the question "Who constructed the first computer ?" will be touched.

[1] Translated by the author

Corresponding to the title here we refrain from mention the scientific work not directly connected to the development of computing devices.

References

1. De Beauclair, W,: Vom Zahnrad zum Chip. Genser, Düsseldorf, 1999
2. Jänike, J., Genser, F.: Deutsche Computerpioniere. o.V. 2nd ed., 1995
3. Mons, W., Zuse, H., Vollmar, R.: Konrad Zuse. Ed. Freiberger-Stiftung, 2005
4. Zuse, K.: Der Computer — Mein Lebenswerk. Springer, Berlin, Heidelberg, New York, 1984
5. Zuse, K.: The Computer — My Life. Springer, Berlin, Heidelberg, New York, 1993
6. Williams, M.R.: A History of Computer Technology. IEEE Computer Society Press, Los Alamitos, 2nd ed., 1997

Ramon Llull's Ars Magna

Thessa Jensen

Institute for Communication and Psychology, Aalborg University
Aalborg, Denmark
thessa@hum.aau.dk

The Great Art of Ramon Llull — the Ars Magna — must be seen as one of the basic philosophical approaches to formalisation of thought, language, and knowledge; conceived and written in the late 13th century by a lay-monk whose life alone would be worth a Hollywood movie.

In this paper I will take a brief look at Llull's life and work, before explaining the four main parts of his Ars Magna. Finally, I will try to give a new perspective on how the Ars Magna still might be a viable and valuable approach to understand some of the challenges and possibilities found in computer science and ethics.

Vita

Llull was born in 1232 in Palma de Mallorca, a melting pot for different cultures and religions at the time. Being educated at the king's court, Llull learned the trade of the troubadour as well as reading and writing in Catalan. He became a devout Christian later in life only after he had married. Jesus showed himself to Llull on several occasions, and eventually Llull resumed his rather debauched life and decided to dedicate the rest of his life to three purposes, which were to become a missionary and die for Christ, to develop and write the Ars Magna, and to build monasteries which should teach various languages [1,2].

The rest of his life, Llull spent travelling around the Mediterranean in an effort to convince Muslims, especially, of the truth of the Christian faith. He soon discovered that the main challenge was to explain the divine Trinity to non Christians. Furthermore, he realised that culture and language barriers must be taken into account when he tried to explain the Christian faith. Instead of focussing on the differences, Llull sought out the similarities, going as far as copying the worshipping style of Muslims.

Legend has it that Llull was stoned to death in the city of Tunis in 1316 by an angry mob of Muslims, unable to dismantle his arguments for the primacy of the Christian faith. His dead body was brought back to Mallorca, and the people of Mallorca have since tried to have Llull canonised as a saint.

Ars Magna

A few years before his death Llull began to write the most thorough and final version of his Ars Magna, the *Ars Generalis Ultima* [3]. The books explain the different figures of the Ars, its principles, questions, descriptions, and combinations.

Figure A, which is the divine figure, contains the nine divine or basic principles. It is made up by two or three concentric circles on top of each other. The inner circles contain the nine letters B to K (J is missing in the Latin alphabet and the outer circle has the nine principles written on it. The combinations of letters with principles are used to construct logical arguments and syllogisms.

The centre of the figure T is made up by three triangles on top of each other. Each triangle points at three different letters in the inner circle around the triangles. Each letter has a principle attached. The outer circle explains the relative principles.

The third figure as well as the fourth figure are combinatoric figures, containing pairs of two letters (third figure) or possible pairs of three letters (fourth figure, in which the different circles can be moved to find new combination of the nine letters).

Finally, the alphabet of the Ars Magna together with an extensive list of possible combinations and their explanations are part of the Ars Generalis Ultima.

Llull saw his Ars as a tool for an amiable and logical discussion among peers. The divine principles as well as the relative principles were common ground for the theological and philosophical trained religious leaders. Through the design of the different figures in his Ars, Llull allowed a discussion which was removed from the holy scriptures and their interpretation, instead revolving around understanding the very nature of belief, life, and God as such.

Computer Science?

Llull was an inspiration for later scientists, most notably Giordano Bruno, Athanasius Kirchner, Agrippa of Nettesheim and Gottfried Wilhelm Leibniz, whose dissertation *De Arte Combinatoria* begins with a discussion of Llull's Ars Magna. Umberto Eco also mentioned Llull in his book *The Search for the Perfect Language* in which Eco describes the quest for developing or discovering the most basic language which would enable people to understand or translate everything easily into another language. The same quest can be found in the work of artificial intelligence and knowledge representation, which seeks to formalise language and knowledge in a way which can be translated into a computer program.

And as Fidora's and Sierra's [4] anthology *Ramon Llull: From the Ars Magna to Artificial Intelligence* shows, Llull's influence and relevance is profound in today's work on topics ranging from conceptual graphs and logical analysis, social choice theory and adaptive reasoning to Llull's influence on Peirce's pragmatic thinking.

Llull *is* important, even now, on a whole other level. His ethical considerations when he wanted to convince people of the one true faith can be found in modern philosophers like e.g. Knud E. Løgstrup and Zygmunt Bauman. By using a list of commonly acknowledged principles and combinatoric rules, Llull turns missionary persuasion into a Habermasian dream of communication among equals.

References

1. Bonner A.: Doctor illuminatus. Princeton University Press (1993).
2. Platzeck E. W.: Das Leben des seligen Raimund Lull: die" Vita Coetanea" und ausgewählte Texte zum Leben Lulls aus seinen Werken und Zeitdokumenten. Patmos-Verlag (1964).
3. Lullus, R.: Ars Generalis Ultima. Minerva GmbH (1970).
4. Fidora A., Sierra C. (eds): Ramon Llull: From the Ars Magna to Artificial Intelligence. Barcelona: Artificial Intelligence Research Institute (2011).

The 19th-Century Crisis in Engineering

Hartmut Bremer

Institut für Robotik, Johannes Kepler Universität Linz
hartmut.bremer@jku.at

At the end of the 19th century, *applied* (or technical) mechanics, as one of the basics of technical development, found itself a desolate state, due largely to the refusal of its practitioners to recognize the influence of kinetics on (spatial) motion. They had failed to keep up with developments in the science underlying their craft and were unable to keep pace with the speeds of such systems as the steam engine. On the other hand, *theoretical* (or rational) mechanics was already well established, mainly (but not restrictively) in conservative astrodynamics. Into this critical situation, two scientists began to bild a bridge, from two different sides: August Föppl (1854-1924) and Felix Klein (1849-1925).

August Föppl represents *Technical Mechanics*. He had studied Civil Engineering and taught fifteen years at the vocational school in Leipzig. In 1892 he attained a professorship for agricultural engineering in Leipzig. Two years later he moved to Munich where he stayed until his death in 1924. It is remarkable that he already introduced vector analysis, and he was the first one to give an explanation to the word wide unbelieved *gyro experimental results* from Carl Gustav de Laval (1845-1913) [1] (later also investigated by Jeffcott (1877-1937)).

The five years older **Felix Klein** was a mathematician with strong interests in *Rational Mechanics*. He obtained his first chair (geometry) in Erlangen, 23 years old, from where he moved 1875 to Munich (analytical geometry), 1880 to Leipzig (geometry) and 1886 to Göttingen (mathematics). Together with his assistant Arnold Sommerfeld (1868-1951), he published a famous book on *gyrodynamics* [2]. The Gyro is the typical representative for spatial dynamics.

Through Klein's influence, **Karl Heun** (1859-1929) attained a professorship in Karlsruhe 1902. Heun had studied mathematics in Halle and Göttingen and earned his habilitation degree 1886 in Munich where he stayed for three years as a private lecturer and then changed to Berlin as a senior teacher. There he met a group of engineers whose problems had grown seemingly insurmountabe. Karl Heun, with his paper from 1900 [3], set the course towards analytical mechanics.

In Karlsruhe, **Georg Hamel** (1877-1954) became Heun's assistant, during which time period Hamel published his habilitation thesis [4]. Heun's and Hamel's contributions were strongly based on Lagrangian mechanics. It was due to Felix Klein that outstanding scientists like Heun and Hamel could eventually bring engineering and natural science back together.

Over the centuries. In the middle of the 19th century, technical universities had been founded all over europe, mainly based on the french école polytechnique from 1794 where Joseph Louis de Lagrange (1736-1813) was teaching from 1797 on, after he had left Berlin ten years before (where he was Euler's successor). Already in 1764 he had won the french academy award [5]. In [5] he formulates for the first time $\int \delta\mathbf{r}^T(\ddot{\mathbf{r}}dm - d\mathbf{f}) = 0$: the *Lagrange-Principle* (which up to the time being has been confused with d'Alembert's Principle [6] which has nothing in common). This breakthrough is impressively demonstrated in his *Analytical Mechanics* [7] where he calls it the "general formula of dynamics" being the basis for his (so-called) analytical methods – but also for the later (so-called) synthetical method(s). No question: Lagrange's Principle from 1764 is a milestone in dynamics and represents the basis of mechanics as modern as can be.

"Practical application of mechanics at first needs to understand its basics" says Föppl 1899, [1], and needs adequate mathematical treatment. However, as Heun puts it 1900, [3], "in view of complex kinetic problems, the intensive knowledge of Lagrange [rational mechanics], Gauss [numerical integration] and Riemann [projective geometry] will lead to success rather than the tedious search in integral tables and engineer calendars. We should, however, not forget that these ingenious mathematicians had been far away from technical applications; the translation of their ideas into a "homespun" form which is needed here [technical mechanics] is by no means an easy task".

In 1905, Klein initiated the institute of applied mechanics in Göttingen. Its directors became two of Föppl's students, namely Ludwig Prandtl (1875-1953), the famous fluid dynamicist, followed by Max Schuler (1882-1972) who developed the *gyro compass.* Under their guidance, Kurt Magnus (1912-2003) approved his PhD (1937) and habilitation theses (1943). (After WWII, he was deported to the USSR, more than seven years imprisoned and forced to do reseach on rocket control). Magnus founded the second chair of mechanics in Munich (1966). His book from 1971 [8] comprises the development up to that time, *Gyrodynamics* representing spatial dynamics at its best. He underlines: "I abstain from specialized mathematical tools when the desired equilibrium between effort and success gets lost". Clearly, things are going on and sometimes need special tools, but it is not constructive to burden the whole consideration with side views. This goes along with Klein's statement at the very beginning [9]: "The exact university sciences have lost contact with the living world in a threatening manner. They look for fame in a self-chosen isolation".

The circle is closed, the 19th century crisis in engineering is overcome. Let us wait for the next.

References

1. A. Föppl, Vorlesungen über Technische Mechanik (B.G.Teubner, Leipzig, 1899).
2. F. Klein, A. Sommerfeld, Theorie des Kreisels (B.G.Teubner, Leipzig, 1897).
3. K. Heun, Die kinetischen Probleme der wissenschaftlichen Technik, in: Jahresberichte der DMV, IX,2 (1900).
4. G. Hamel, Die Lagrange-Eulerschen Gleichungen der Mechanik, ZAMP, 1-57 (1904).
5. J. de Lagrange, récherches sur la libration de la lune (1764), reprint: Oeuvres de Lagrange **6**, (Gauthiers-Villars, Paris, 1873).
6. J. d'Alembert, traité de dynamique, second edition, (David, Paris, 1758).
7. J. L. de Lagrange, Méchanique analytique (Desaint, Paris, 1788).
8. K. Magnus, Kreisel, Theorie und Anwendungen (Springer, Berlin, Heidelberg, 1971).
9. K. Magnus, Mechanik bei B.G.Teubner (Teubner-Stiftung, Stuttgart, 1986).

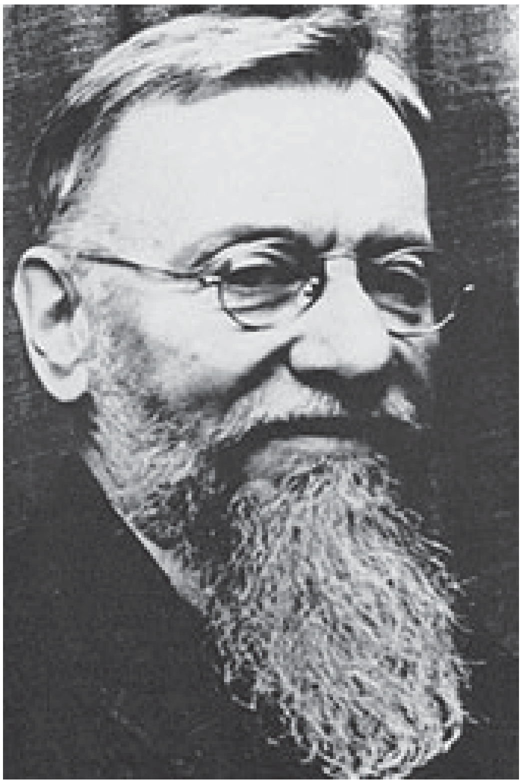
Nicolas Rashevsky: Mathematical Biophysicist

Paul Cull

Computer Science
Kelley Engineering Center
Oregon State University
Corvallis, OR
97331, USA
pc@cs.orst.edu

Nicolas Rashevsky was a pioneer in applying mathematics to biology. He is perhaps best known for his creation of neural net models and his applications of these models to a wide variety of problems in physiology and psychology.
His journal, the Bulletin of Mathematical Biophysics (renamed Bulletin of Mathematical Biology), and his two volume tome, Mathematical Biophysics (Dover, 1960), inspired others to use mathematical models in biology.

Here we give a brief description of Rashevsky's career and discuss his lasting (or not so lasting) influence.



McCulloch's Relation to Connectionism and A.I.

Roberto Moreno-Díaz, Gabriel de Blasio

IUCTC - Universidad de Las Palmas de G.C.
rmoreno@iuctc.ulpgc.es
gabriel.deblasio@ulpgc.es

Abstract

It is normally accepted that the beginnings of modern computing connectionism can be traced to McCulloch's and Pitt's paper of 1943 [1]. The important points of their historical contributions is however mislead by the drift that developments on theoretical computer architectures took after the 50's. The so called Artificial Neural Nets and subsequent connectionist philosophy were actually fixed by Rosenblatt's Perceptrons and his detractors, plus the more recent adenda of multi-layer perceptrons and back propagation adjusting techniques. They clearly used the basic idea of threshold logic and computation but evolved away from McCulloch-Pitts proposals, towards and in a computer tool of many times questionable power, just as parametric classifiers.

What is apparent, however, is that the Macy's Foundation Meetings from 1943 to 1945 , started by Wiener and McCulloch, and all chaired by the late, provided for the roots of many of present day concepts and ideas for the so called Computational Neurosciences.

On an other side, A.I. appears in the 50's by the hand of McCarthy and Minsky, mostly influenced by mathematical and logician of the caliber of Gordon Pask, Von Neumann and Donald McKay. McCulloch, again, stood aside, in spite of this strong friendship and relations to all of them, even helping seriously in the creation of the MAC Project of Minsky and the A.I. laboratory of MIT in Tech. Square. He always thought however that Good Old-Fashioned Artificial Intelligence (GOFAI) and its successor, Knowledge Engineering contributed nothing to brain understanding, but rather were in most cases "toys or even little monsters".

By a quick reminder of McCulloch's late years activity (1965-1969) we shall try to show how the basic contributions to the computer-brain paradigm of McCulloch came mostly from the two important early papers, the one in 1943 and "How We Know Universals" in 1947. We shall end by reminding some still open questions since his last meetings in Europe (Lisbon, july 1968): on command and control, consciousness, intention, multi-functionality and reliability in the nervous system.

References

1. McCulloch WS, Pitts W (1945) A Logical Calculus of the Ideas Immanent in Nervous Activity. The Bulletin of Mathematical Biophysics 5(4):115–133

Kurt Gödel: A Godfather of Computer Science

Eckehart Köhler and Werner Schimanovich

University of Viena, Austria
eckehart.koehler@univie.ac.at

Abstract

We argue that Kurt Gödel exercized a major influence on computer science. Although not immediately involved in building computers, he was a pioneer in defining central concepts of computer theory. Gödel was the first to show how the precision of the formal language systems of Frege, Peano and Russell could be put to work to prove important facts about those language systems themselves, with important consequences for mathematics. As Hilbert's collaborator, Paul Bernays put it, in his famous Incompleteness Proof Gödel did the "homework" that the people in Göttingen working on Hilbert's Program to prove the consistency of mathematics missed. (Hilbert's Metamathematics assumed that all mathematical proofs could be treated as coding problems, and enciphering is applied arithmetic.) The core of Gödel's Proof also gave exact definitions of the central concept of arithmetic, namely of the recursion involved in mathematical induction (with help from the great French logician Jacques Herbrand). This immediately led to whirlwind developments in Göttingen, Cambridge and Princeton, the working headquarters of major researchers: Paul Bernays and John von Neumann; Alan Turing; and Alonzo Church, respectively. Turing's and von Neumann's ideas on computer architecture can be traced to Gödel's Proof. Especially interesting is the fact that Church and his lambda calculus was the main influence on John McCarthy's LISP, which became the major language of Artificial Intelligence.

Nikola Tesla - A Tribute to his Inventions

[1]Radomir S. Stanković, [1]Milena Stanković, [2]Franz Pichler

[2]Dept. of Computer Science, Faculty of Electronic Engineering, Niš, Serbia
[2]Johannes Kepler University Linz, Linz, Austria

Nikola Tesla (1856 - 1943) can be considered as one of the most important inventors of the 19-th century. His contributions to the invention and development of electromagnetism and electrodynamics are outstanding. Tesla contributed by various patents to other areas of engineering including telecommunications, remote control, and mechanic engineering.

By his studies at the Technische Hochschule Graz, Austria, during 1875 - 1878, and at the University of Prague in 1880, he got the necessary scientific knowledge for his further work. Following his stay in Budapest and Strasbourg, he emigrated in 1884 to the United States to make there his fortune as an engineer and inventor. After a short sketch on Teslas life, the lecture focus on his contribution to AC-power engineering and also to his invention and development of high frequency apparatus of different kind, which today are considered as a part of radio engineering.

With the invention of the polyphase induction motor together with the related dynamos in 1888, Nikola Tesla gave an important contribution to the field of AC-technology. The Westinghouse Company bought from Tesla in 1889 the whole package of AC-patents and manufactured appropriate AC machines based on it. The installation of Teslas polyphase induction dynamos at the Niagara hydro power plant in 1896, can be considered as a highlight of success of AC-technology. The plates fixed on the dynamos showing thirteen patents altogether, contain nine which refer to patents of Nikola Tesla.

Tesla investigated different methods for the generation of high frequency electrical currents. Already in 1890, he developed a high frequency alternator with a special kind of armature which allowed AC generation up to 16 kHz. Later such dynamos came in heavy use for transmitters of oversee-long wave transmitting stations. Another method for the generation of high frequency currents, considered by Tesla, was the use of a Hertzian spark-gap together with a resonance circuit and a ironless step-up transformer, today considered as a ”Tesla coil”. Due to this invention, Tesla can be viewed as one of the inventors of wireless transmitters and radio technology, together with Marconi, Lodge, and Popov. However, Teslas interest was not the wireless transmission of information but that of electrical energy. However, his experiments in New York and Colorado Springs toward that goal, brought no practical success. By lack of financial means, the Wardencliffe project at Long Island could not brought to an end and Tesla had in 1905 to close his laboratory there. This was the end of Teslas plan to establish a ”world system” for the wireless distribution of electric energy. It is important to notice that Tesla also developed, patented (Patent No. 68,809), and demonstrated publicly in 1898, a multi-frequency radio-controlled boat that he called *telautomaton* due to a wireless secure communication between transmitter and receiver.

The renowned Tesla expert, Professor Aleksandar Marinčić of the Faculty of Electrical Engineering, University of Belgrade, Serbia, wrote the following ”Nikola Tesla did not belong to the group of great theoreticians who develop new frontiers of science, or to the class of great practitioners who invent many useful things for our lives. He belonged to a group of pioneers who opened up new field of technology”.

Recommended Reading

Margaret Cheney & Robert Uth, *Tesla - Master of Lighting*, Metro Books, New York, 2001.

Aleksander Marinčić, *Nikola Tesla - The work of a genius*, Gallery of Serbian Academy of Sciences and Art, Belgrade, 2006.

Aleksander Marinčić, ”Nikola Tesla and his contribution to radio development”, in Tapan K. Sakar et al. (eds.), *History of Wireless*, Wiley Interscience, Hoboken, N.J. 2006, Chapter 8, 267 - 289.

Mel Breuer, ”Tesla and AND gates”, *IEEE Design & Test of Computers*, Vol. 24, No. 6, November-December 2007, 624, DOI 10.1109/MDT.2007.206

Charles Proteus Steinmetz: Pioneering Contributions in Electrical Engineering

Franz Pichler

c/o Institute of Digital Circuits
Johannes Kepler University Linz
A 4040 Linz, Austria
telegraph.pichler@aon.at

Abstract

The development of electrical engineering, a century ago, can be considered as one of the most interesting chapters of the history of technology in Europe and North America. The inventors of this time, such as Edison, Tesla, Siemens, Marconi, Morse, Bell, Heaviside, Gramme, and others, are still of strong biographical interest to us.

This lecture should bring the scientific work and the life of a man to our rememberings, a man which is known in Europe only in special scientific circles: Charles Proteus Steinmetz, as he called himself with his americanized first name. Steinmetz, born 1865 in Breslau (Germany), now Wroclaw(Poland), received his fundamental scientific education in old Europe. However, the American continent gave him the chance to apply his talents in full breath, not forcing him to a certain personal life style. In contrary, he could fully keep his most interesting individuality.

His work and inventions concerned the problems which had to be solved by the advent of the practical use of alternating currents. In the construction of dynamos and motors it became necessary to fight against eddy currents which caused losses of power. Steinmetz with his early work on the hysteresis of iron cores of such machines contributed to the solution.. Another important problem which occurred in the use of alternating currents was the design of proper networks for transmission. Steinmetz showed that the use of complex numbers allowed a new characterization of resistors, inductances and capacitors for alternating current circuits such that the Ohm's law was still applicable.

In the history of the General Electric Company the time of 1902, where General Electric was founded and Steinmetz joined the company, until the year 1923, the year in which Steinmetz died, has been called the "Steinmetz era". His inventions, his many books, written for his students at the Union College in Schenectady give enough reasons to consider Charles Proteus Steinmetz as one of the most important electrical engineers of the past.

Important Papers Published by Steinmetz in Early Years

- Das Gesetz der magnetischen Hysteresis und verwandte Phnomene des magnetischen Kreislaufes. ETZ , XIII. Jahrgang, Berlin 1892.
- Die Anwendung komplexer Gren in der Elektrotechnik. ETZ XIV. Jahrgang, Berlin 1893.

Monographies and Textbooks by Steinmetz

- Theory and Calculation of Alternating Current Phenomena, New York 1897.
- Theory and Calculation of Transient Electric Phenomena and Oscillations, New York 1909.
- Radiation, Light and Illumination, New York 1909.
- Electric Discharges, Waves and Impulses, New York 1914.
- Theory and Calculation of Alternating Current Phenomena, New York 1916.
- Theory and Calculation of Electrical Circuits, New York 1917.
- Engineering Mathematics,New York 1917.
- Four Lectures on Relativity and Space, New York 1923.

How Marconi and Gernsback Sparked a Wireless Revolution

James and Felicia Kreuzer

Long Island, New York,USA
wireless@pce.net

Abstract

This paper explores the contributions of Guglielmo Marconi and Hugo Gernsback and shows how the interaction of their individual efforts developed a revolutionary system that was to accelerate a flow of information communications, forming a network which would ultimately lead to creating the current information superhighway. In the early days of wireless, the world's environment was primed and ready for realization of the potential of wireless communications. Marconi assembled a team of technology specialists, developing equipment which quickly paved the way for strengthening the signal and propelling his vision of forming a system of worldwide wireless to fruition. Gernsback provided equipment and the "how to" expertise to the common man, and united experimenters and amateur radio operators through his magazines, EI company offerings, and establishment of the Wireless Association of America and the Radio League of America. Together their efforts, although their separate visions may have been driven by self-serving ambitions, provided an altruistic system that was to create and unite a network of wireless communication and operators ready for deployment when needed during wartime and beyond.

Contributions to Electromagnetic Theory and Telecommunications by Dr. Henning F. Harmuth

Konstantin Lukin, IEEE Fellow

LNDES
Usikov IRE NAS of Ukraine, Kharkiv Ukraine
Lukin.konstantin@gmail.com

Extended abstract

Dr. Henning F. Harmuth has proposed several revolutionary ideas in electromagnetics, radar and communication sciences. In particular, he suggested application of orthogonal Walsh functions in Spread Spectrum Communications; Non-sinusoidal, or Carrier free,or UWB signals in Radar;Large Current Radiator for efficient radiation of such signals, etc. In addition, he suggested modification of Maxwell's equation for adequate description of electromagnetic (EM) signals (squared waveforms) through lossy media. Introduction of vector potential associated with magnet dipoles and currents into Hamiltonian in the Equation of Quantum Electrodynamics allowed to avoid a divergence in their solutions. He introduced a discrete model of space-time when considered the basic equations of contemporary physics. Finally, he suggested application of information theory in physics and published these results in Russian first and in English later on.

In the paper I will summarize those contributions, describe their significance for science and give some generalization and physical explanations of Harmuth's ansatz.

As we know, two of Maxwell's equations, Ampere's law modified by Maxwell and Faraday's law of electromagnetic induction, are always valid for a medium containing no electric and magnetic charges either free or bound ones.When considering electromagnetic fields in a medium one has to add so-called constitutive equations which establish relations between the fields and parameters of the medium. In this way, one may consider many modifications of the overall set of the equations governing electromagnetic fields in media. This is the commonly accepted standpoint in contemporary electrodynamics. If one needs to consider *EM signal* propagation through a lossy medium, such as a gas, seawater, or dielectric solids, with dissipation of the energy of the *electromagnetic* field, one will necessarily need to describe this dissipation, and the simplest way to do that is to use Ohm's law connecting electric field and electric current density associated with the motion of free electrons or ions.This may be done because of the existence of electrons or dipoles as the carriers of electric currents. At the same time, nobody introduces a similar law to describe losses associated with the magnetic field because the existence of free magnetic charges has not been proven, but we know that magnetic dipoles exist just as electric ones. At this point it is worth to note that the electromagnetic field losses due to interaction with bounded charges or dipoles in dielectric and magnetic materials are usually described in terms of imaginary parts of dielectric permittivity and permeability associated with the electric and magnetic dipoles of the medium, respectively. Considering propagation of electromagnetic signals in the form of rectangular pulses or step-functions through a lossy medium, Dr. Henning F. Harmuth faced the problem of singularity in the expression for the magnetic field if the pulse was excited by electric excitation. In order to go around this problem, he suggested to *modify* Maxwell's equations [1] via introduction into Faraday's law a term proportionate to the magnetic field, i.e. he suggested to introduce 'Ohm's law' for magnetic monopole or dipole current densities. Surprisingly, this step eliminated the singularity mentioned above even if the medium's magnetic conductivity will be put to zero, but in the solution obtained. Dr. Henning F. Harmuth called the equations obtained in this way *Modified Maxwell's equations* for lossy media. I have suggested *physical* justification for that modification [2] which is briefly explained below. Let's recall the microscopic picture of the electric Ohm's law. The current density in a conducting medium is proportionate to the electric field strength because the electrons being accelerated by the electric field experience multiple inelastic collisions with heavy atoms, transferring portion of their kinetic energy to heating of the crystal lattice. This heating is due to a huge number of electron collisions transforming the energy and changing the *shape* of non-polarized neutral atoms which leads to *varying of their dipole momentum in time*. This implies the generation of additional microscopic currents in the lossy medium, and the magnetic component of the EM waves will necessarily transfer portion of its energy to these currents, which may be interpreted and described as 'magnetic Ohm's law' suggested by Harmuth. In this way, the conventional Ohm's law in a lossy medium is to be always supplemented with a magnetic Ohm's law! Here is another reasonable problem, how strong will be this additional current? Normally, the related losses should be much less compared to the losses associated with the electric Ohm's law and therefore in many cases they may be ignored. However, this is not the case when studying the propagation of step-like signals through lossy media, in particular, over extremely long distances since small effects will be accumulated during the long distance of propagation (e.g. interstellar propagation of EM signals [3]), and sooner or later they will make an appreciable contribution to the solution.

References

1. Harmuth H.F. Correction of Maxwell's Equations for Signals I // IEEE Transaction on Electromagnetic Compatibility – Nov. 1986.– V. EMC–28, # 4. P. 250–272.
2. Lukin K.A. On the Description of Electromagnetic Signal Propagation through Conducting Media. Electromagnetic Phenomena , 2007, V.7, #1(18), pp174-179.
3. Harmuth H.F. and Lukin K.A. Interstellar Propagation of Electromagnetic Signals. – N.-Y.:Kluwer Academic/Plenum Publishers. – 2000.

Quantifying the Spread of an Epidemic with Latency Period and Nonlinear Incidence Rate

M.J. Lopez-Herrero

Faculty of Statistical Studies, Complutense University of Madrid, 28040 Madrid
Lherrero@ucm.es

Abstract. Our interest is to quantify the spread of an infective process with latency period and generic incidence rate that takes place in a finite and homogeneous population. Within a stochastic framework, two random variables are defined to describe the variations of the number of secondary cases produced by an index case inside of a closed population.

Keywords: Nonlinear Incidence Rate, Stochastic SEIR Epidemic Model, Index Case, Secondary Cases

1 Introduction

Epidemic models are widely used for understanding the mechanism that underlies the spread of an infectious disease. A very large number of epidemiological models involves a compartmental division of individuals. It is also commonly assumed that individuals make contacts at random showing no preferences. The fundamental compartmental model for the study of an infectious disease that confers immunity is the SIR proposed by Kermack & McKendrick [1], where individuals are classified as susceptible to the infection, labeled S, infected by the pathogen, I, or recovered from the infection, R.

One drawback of the SIR model is that it assumes that after the transmission of the disease to a susceptible individual, the individual becomes immediately infective. However, the process of transmission occurs in most cases with an initial transfer of a very small number of bacterial cells or viruses. During this period the individual is in some sense infected but not yet infective (latent period). Such an individual is referred to as exposed (E). The SEIR model has a slower growth rate, since after the pathogen invasion the susceptible individuals need to pass through the exposed class before they can contribute to the transmission process.

This communication focus on the study of the spread of a communicable disease involving latency period and a general mode of transmission so, we generalize the classic SIR model in two ways. First we deal with an SEIR model. Second, we consider a transmission of nonlinear type.

The mode of transmission determines the possible response of the disease upon study. Its mathematical description is based in a function called force of infection or incidence rate. In most models transmission is assumed to occur via so called mass action [2], involving a bilinear function of S and I. This particular choice makes that theoretical models show an exponential growth in the early part of the epidemics [1,2].

Measuring the transmission potential in a population is the role of R_0, the basic reproduction number (see [3] and [4]). This is the most widely used measure of disease spread in epidemiology and population dynamics. R_0 is a threshold parameter which tries to measure the initial spread of an epidemic process by estimating the average of secondary cases of infection arising from an index case in a virgin population, during its infectious period. Artalejo & Lopez-Herrero include in [5] a summary of remarkable features and drawbacks of R_0, which is supported by an important set of references.

In the stochastic framework it is frequently assumed a value for R_0 inherited from the deterministic counterpart. In that sense, for our stochastic SEIR model with non-linear incidence rate, we call basic reproduction number to the quantity appearing at expression (3.7) in the paper by Korobeinikov & Maini [6]. We remark that, for a deterministic model without vital dynamics, the expression for R_0, is the same in SIR and SEIR models; showing that the average number of individuals infected by an index case does not depend on the exposed population. And one wonders if this coincidence is not a consequence of estimating an average number in a large population.

For an epidemic process described by a continuous time Markov chain we quantify the steady-state behavior of the epidemic spread by means of two random variables. Namely, R_{e0}: the exact reproduction number and R_p or the population transmission number. The aim of this communication is two fold:

- To extent the existing methodology to a more involved epidemic model and to find stable computational schemes able to handle the high dimensionality of the state spaces arising when an additional component is introduced in the Markovian model representing the epidemic evolution.
- To study the influence of the latency parameter to the epidemic spread in an SEIR model, when transmission depends on a general nonlinear incidence function.

References

1. Kermack, W.O., McKendrick, A.G.: A contribution to the mathematical theory of epidemics. Proc. R. Soc. Lond. A. 115, 700-721 (1927)
2. Anderson, R.M., May, R.M.: Infectious diseases of humans: dynamics and control. Oxford University Press, Oxford; (1991)
3. Heesterbeek, J.A.P., Dietz, K.: The concept of R_0 in epidemic theory. Stat. Neerl. 50, 89-110 (1996)
4. Hethcote, H.W.: The mathematics of infectious diseases. SIAM Review. 42, 599-653 (2000)
5. Artalejo, J.R., Lopez-Herrero, M.J.: On the exact measure of disease spread in stochastic epidemic models. Bull. Math. Biol. 75, 1031-1050 (2013)
6. Korobeinikov, A., Maini, P.K.: Non-linear incidence and stability of infectious disease models. Math. Med. Biol. 22, 113-128 (2005)

Coexistence of multiple infectious agents in epidemic models and perturbation analysis of related LD-QBD processes

A. Gómez-Corral

Instituto de Ciencias Matemáticas CSIC-UAM-UC3M-UCM,
Calle Nicolás Cabrera 13-15, 28049 Madrid, Spain
antonio.gomez@icmat.es
http://www.icmat.es/antonio.gomez-corral

Abstract. We adapt arguments from the paper by Caswell [1] to *level-dependent quasi-birth-and-death* (LD-QBD) processes, which constitute a wide class of structured Markov chains. Specifically, we provide the perturbation analysis of various probabilistic characteristics of finite LD-QBD processes, including first-passage times and hitting probabilities, the maximum level visited by the process, and the stationary distribution. We illustrate the approach by means of the multi-type versions of SI and SIS epidemic models.

Keywords: epidemic model · hitting time · matrix calculus · perturbation analysis · QBD process

Recently, Caswell [1] uses matrix calculus to provide the sensitivities and elasticities of the dynamics of absorbing continuous-time Markov chains (CTMCs) to arbitrary parameters, which may correspond to either the transition rates themselves or functions of these rates that have substantive meaning. More concretely, Caswell [1] derives formulas for the sensitivity and elasticity of the moments of the time to absorption, the time spent in each transient state, and the number of visits to each transient state before absorption, being the resulting expressions applied to a model for the progress of colorectal cancer. The results in [1] are closely related to the investigation of absorbing Markov chains in discrete-time, with applications to demographic and ecological problems in [2].

In this talk, the aim is to complement the general treatment of Caswell [1, 2] by taking advantage of the sparsity of the underlying matrices arising when analyzing a class of structured CTMCs. Specifically, the interest is in level-dependent quasi-birth-and-death (LD-QBD) processes, which are CTMCs in two-dimensions, the *level* and the *phase*, such that the process does not jump across several levels in one transition. In analyzing LD-QBD processes, matrix-analytic methods [4, 6] are popular as modeling tools that allow us to construct and study, under a unified and algorithmic tractable framework, a variety of stochastic models, such as epidemic models, inventory problems, reliability systems, retrial queues and two-species competition processes, among others. The starting point in our analysis is the paper by Gaver et al. [3], where the emphasis is upon obtaining numerical methods for evaluating stationary distributions and moments of first-passage times in finite LD-QBD processes.

The results to be presented here deal with perturbation analysis of finite LD-QBD processes as an important tool for understanding how certain parameters –inherently linked to the dynamics of the model– determine the properties of the process, as well as in predicting how small changes in the environmental conditions will modify the outcome. We present an efficient computational approach to the perturbation analysis of finite LD-QBD processes in terms of

(i) First passage times to a certain level $L(0)$ and related hitting probabilities;
(ii) The maximum level visited by the process before reaching states in level $L(0)$; and
(iii) Stationary measures.

Our results are motivated by, but not restricted to, epidemic models, whence we include two examples describing the spread of two infectious agents among a finite population of individuals, under the assumption that each infectious agent confers immunity against the other agent. In the context of the resulting SI_1, I_2 and SI_1, I_2S epidemic models analyzed by Saunders [7] and Kirupaharan et al. [5], respectively, first-passage times permit us to study the length of an outbreak, the stationary distribution is a long-run description of the epidemic, and the maximum level visited by the LD-QBD process is seen as an important measure in studying infectious peaks during an outbreak. In terms of these random indexes, the perturbation analysis allows us to quantify the effects of changes in the contact and recovery rates (or functions of these rates) on the spread of the infectious disease.

References

1. Caswell, H.: Perturbation analysis of continuous-time absorbing Markov chains. Numerical Linear Algebra with Applications 19, 901-917 (2011)
2. Caswell, H.: Sensitivity analysis of discrete Markov chains via matrix calculus. Linear Algebra and its Applications 438, 1727-1745 (2013)
3. Gaver, D.P., Jacobs, P.A., Latouche, G.: Finite birth-and-death models in randomly changing environments. Advances in Applied Probability 16, 715-731 (1984)
4. He, Q.-M.: Fundamentals of Matrix-Analytic Methods. Springer, New York; (2014)
5. Kirupaharan, N., Allen, L.J.S.: Coexistence of multiple pathogen strains in stochastic epidemic models with density-dependent mortality. Bulletin of Mathematical Biology 66, 841-864 (2004)
6. Latouche, G., Ramaswami, V.: Introduction to Matrix Analytic Methods in Stochastic Modeling. ASA-SIAM, Philadelphia; (1999)
7. Saunders, I.W.: Epidemics in competition. Journal of Mathematical Biology 11, 311-318 (1981)

On Fractional Stochastic Modeling of Correlated Neuronal Activity *

Enrica Pirozzi

Dipartimento di Matematica e Applicazioni, Università di Napoli FEDERICO II,
Via Cintia, 80126, Napoli, ITALY
{enrica.pirozzi}@unina.it

Abstract

Features of the neuronal dynamics can be explained as consequences of several correlated causes. For instance, spike-frequency adaptation is often explained as a consequence of the dynamics of membrane neuronal gates or of the action of ionic currents, as those related to voltage-dependent potassium channels ([6],[7]). Moreover, the membrane voltage is affected by dynamics evolving on different time scales, as, for instance, that of slow calcium dependent channels. Briefly, by considering all involving dynamics, the value of membrane voltage cannot be represented by a Markovian process, but models with correlations are mandatory. Recently, some models have been proposed to describe the no-memoryless neuronal voltage by using fractional derivatives. In ([10]), taking into account the action of membrane conductances and in order to describe the timing adaptation, the following fractional Leaky Integrate-and-Fire (LIF) model is proposed:

$$C_m \frac{d^\alpha V}{dt^\alpha} = -g_L(V - V_L) + I_{inj}, \quad \text{if} \quad V > V_{\text{th}}, \text{ then } V \to V_{\text{reset}} \tag{1}$$

where V is the neuronal membrane potential, α is the order of the fractional derivate ($0 < \alpha \leq 1$) and the injecting current I_{inj} includes a Gaussian white noise. When $V > V_{\text{th}}$ a spike is generated. The fractional stochastic approach for neuronal modeling can be also found in ([1], [2], [9]) in which some memory effects and correlations are involved.
Alternatively, correlated inputs can be used to model the firing activity embodying other evolving phenomena. The following neuronal stochastic model with time correlated inputs is considered in ([8]):

$$\theta \frac{dV}{dt} = -V + \eta(t), \quad (\text{if} \quad V > V_{\text{th}}, \text{ then } V \to V_{\text{reset}}) \tag{2}$$

where the temporally correlated (colored) inputs $\eta(t)$ is a Gaussian stochastic process such that

$$\mathbb{E}[\eta(t)] = 0, \quad \mathbb{E}[\eta(t)\eta(s)] = \frac{1}{2\tau} \exp\left\{-\frac{|t-s|}{\tau}\right\}.$$

* Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems"

Furthermore, in order to take into account the adaptation phenomenon due to the effect of variations in the calcium concentration, in [6] a time-inhomogeneous LIF model is proposed for the neuronal activity, by using the following stochastic differential equation:

$$dV(t) = -\left[\frac{V(t)-\rho(t)}{\theta(t)} - \mu\right] dt + \sigma dW(t) \tag{3}$$

where $\rho(t)$ and $\theta(t)$ are the time-dependent resting potential and decay time and $W(t)$ the standard Brownian motion. Even though uncorrelated inputs are considered, time dependent functions are adopted to explain the action of multiple time-scale dynamics. In this case, the theory of Gauss-Markov and the First Passage Time problem turned out especially useful (see [3]-[6]).

Due to the property to include different scales and ranges of time, the fractional stochastic models seem to be more general and powerful than models including colored noise and modified LIF models. Here, the models (1)-(3) are studied and related results about firing densities will be carried out by using numerical procedures and simulations. Comparisons and suitable relationships between the above models will be provided. The use of fractional Brownian motion $W(t, \alpha)$ (and fractional noise) in place of $W(t)$ in LIF-type models (3) will be investigate.

References

1. Armanyos M., Radwan, A.G. Fractional-order Fitzhugh-Nagumo and Izhikevich neuron models. 2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 1-5, (2016)
2. Bernido C.C. and Carpio-Bernico M.V. On a Fractional Stochastic Path Integral Approach in Modelling Interneuronal Connectivity, Int. J. Mod. Phys. Conf. Ser. 17, 23–33, (2012)
3. Buonocore, A., Caputo, L., Pirozzi, E., Ricciardi, L.M.: On a Stochastic Leaky Integrate-and-Fire Neuronal Model, Neural Computation, 22, 25582585, (2010)
4. Buonocore, A., Caputo, L., Pirozzi, E., Ricciardi, L.M.: The first passage time problem for gauss-diffusion processes: Algorithmic approaches and applications to lif neuronal model. Methodol. Comput. Appl. Prob., 13, 29–57 (2011)
5. Buonocore A., Caputo L., Nobile A. G., Pirozzi E., Restricted Ornstein-Uhlenbeck process and applications in neuronal models with periodic input signals. Journal of Computational and Applied Mathematics. Vol. 285. Pag.59–71 (2015)
6. Buonocore A., Caputo L., Carfora M. F. , Pirozzi E., A Leaky Integrate-And-Fire Model With Adaptation For The Generation Of A Spike Train. Mathematical Biosciences and Engineering Volume 13, Number 3, pp. 483-493 (2016)
7. Kim H. and Shinomoto S., Estimating nonstationary inputs from a single spike train based on a neuron model with adaptation, Math. Bios. Eng., 11 (2014), 49-62.
8. Kobayashi R., Tsubo Y., and Shinomoto S., Made-to-order spiking neuron model equipped with a multi-timescale adaptive threshold. Frontiers in Computational Neuroscience , 3-9 (2009).
9. Kumar R.U., Mondal A., Dynamics of fractional order modified Morris-Lecar neural model, Network Biology, 5(3): 113–136, (2015)
10. Teka W., Marinov T.M., and Santamaria F., Neuronal Spike Timing Adaptation Described with a Fractional Leaky Integrate-and-Fire Model, PLoS Comput Biol. 10(3): e1003526 (2014)

Estimating the exceedance probability in environmental data *

Giuseppina Albano, Michele La Rocca, Cira Perna

Dept. of Economics and Statistics, University of Salerno, Italy

Abstract

Potential health effects of air pollution have been object of a deep study in recent years. Exposure to pollutants such as airborne participate matter has been associated with increases in mortality and in respiratory disease. These effects have been found in short and long term studies. In response, the European Union has developed an extensive body of legislation which establishes health based standards and objectives for a number of pollutants in air.

On the other hand, air quality data, such as all environmental data, are tipically characterized by some stylized facts, such as non-stationarity, non linearity, seasonality, conditional heteroscedasticity and missing data. In particular, missing values make difficult to determine whether the limits set by the European Community on certain indicators of air quality are fulfilled or not. Indeed, due to missing values, the number of exceedances per year of PM_{10}, that is particulate matter 10 micrometers or less in diameter, and other air quality indicators is often heavily underestimated and no environmental policy is applied to protect citizen health. In this perspective it becomes fundamental to estimate the probability that each indicator has to have exceeded the admitted limit.

In this paper we propose a procedure for estimating the probability of exceeding the legal limit for a certain air quality indicator. In particular we focus on the probability for PM_{10} at a certain day t to exceed the value of 50 $micrograms/m^3$.

The suggested procedure combines a local estimator for the trend-cycle and a GARCH model with exogenous components as an estimator of the detrended time series. The first choice is justified in order to have flexible local structures which are not influenced by missing values outside the estimation window. The latter choice appears to be necessary since the detrended time series might show a non linear structure due both to the intrinsic characteristic of the data and to the cycle-trend estimation step. Indeed, the difficult task of selecting tuning parameters in that step might possibly induce neglected nonlinearities in the detrended series. Also, GARCH model is able to capture heteroschedasticity in the data. Finally, we choose to include exogenous variables in the model in order

* (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems.")

to include the natural dependence from data of PM_{10} in near areas due to same geographic and weather conditions.

Finally, a bootstrapping procedure is implemented in order to estimate the probability to observe an exceedance of an established limit.

In order to validate the procedure a simulation study is performed. An application to real data is also presented and discussed.

References

1. Albano, G., La Rocca, M., Perna, C.: Non Linear Time Series Analysis of Air Pollutants with Missing Data. Advances in Neural Networks-Series Smart Innovation, Systems and Technologies 54, 371–378 (2016).
2. Draghicescu, D., Ignaccolo, R.: Modeling threshold exceedance probabilities of spatially correlated time series. Electron. J. Stat. 3, 149-164 (2009).
3. Health — Particulate Matter — Air & Radiation — US EPA. Epa.gov. 2010-11-17.
4. Junger, W.L., Ponce de Leon, A.: Imputation of missing data in time series for air pollutants. Atmos. Environ. 102, 96104 (2015).
5. Noor, M.N., Al Bakri, A.M.M., Yahaya, A.S., Ramli, N.A., Fitri, N.F.M.Y.: Estimation of Missing Values in Environmental Data Set using Interpolation Technique: Fitting on Lognormal Distribution. Aust. J. Basic Appl. Sci. 7(5), 336-341 (2013).
6. Ole Raaschou-Nielsen et al. Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). Lancet Oncol. 14(9), 813822 (2013).
7. Pèrez-Gonzàlez, A., Vilar-Fernàndez, J. M., Gonzlez-Manteiga, W.: Asymptotic properties of local polynomial regression with missing data and correlated errors Ann. Inst. Stat. Math. 61, 85109 (2009).
8. Yahaya, A.S., Ramli, N.A., Ahmad, F., Nor, N.M., Bahrim, M.N.H.: Determination of the Best Imputation Technique for Estimating Missing Values when Fitting the Weibull Distribution. Int. J. Appl. Sci. Technol., 1(6), 278-285 (2011).

An Approach to Obtaining Sharp Bounds on the Rate of Convergence for Finite Continuous-time Markov Chains

Alexander Zeifman[1], Alexander Sipin[2], Victor Korolev[3], and Galina Shilova[2]

[1] Vologda State University; Institute of Informatics Problems FRC CSC RAS; ISEDT RAS, Russia; a_zeifman@mail.ru
[2] Vologda State University
[3] Faculty of Computational Mathematics and Cybernetics, Lomonosov Moscow State University; Institute of Informatics Problems FRC CSC RAS

We deal with sharp bounds of the rate of convergence for a wide class of finite continuous-time Markov chains.

As it is known, the problem of finding sharp bounds of the rate of convergence to the limiting characteristics for Markov chains is very important for a number of reasons:
(i) it is easier to calculate the limit characteristics of a process than to find the exact distribution of state probabilities, (see, for instance [14]);
(ii) the best bounds of perturbations require the corresponding best bounds on the rate of convergence, see [3, 5, 6, 13];
(iii) sharp bounds of the rate of convergence are required to obtain truncation bounds which are uniform in time, see [11].

The general approach is closely connected with the notion of logarithmic norm and the corresponding bounds for the Cauchy matrix. It was first studied for birth-death processes (with possible catastrophes), see details and references in [1, 2, 10], and for Markovian queueing models with batch arrivals and group service, see [12]. An essential part of this approach is the special transformations of the reduced intensity matrix. This transformation was proposed in [8] and applied to general inhomogeneous birth-death models in [9]. Here we apply this approach and the same transformation to two new classes of inhomogeneous continuous-time Markov chains describing combined queueing systems with state-dependent arrival intensity and batch service; and vice versa for queueing system with batch arrivals and state-dependent service, see, for instance, [7] and [4]. The first study of the corresponding countable models was carried out in [15]. The situation of finite state space provides a possibility of, first, to simplify the reasoning and, second, to obtain essentially more precise bounds.

Acknowledgments. The research is supported by the Russian Foundation for Basic Research, projects no. 15-01-01698,15-07-05316, and by Ministry of Education and Science.

References

1. Van Doorn, E. A., Zeifman, A. I., Panfilova, T. L.: Bounds and asymptotics for the rate of convergence of birth-death processes. Theory Probab. Appl. 54, 97–113 (2010)
2. Granovsky, B. L., & Zeifman, A. I. : The N-limit of spectral gap of a class of birthdeath Markov chains. Applied Stochastic Models in Business and Industry, 16(4), 235–248 (2000)
3. Kartashov, N. V.: Criteria for uniform ergodicity and strong stability of Markov chains with a common phase space. Theory Probab. Appl., 30, 71-89 (1985)
4. Li, J., Zhang, L.: Decay property of stopped Markovian bulk-arriving queues with c-servers. Stochastic Models, 1–13 (2016)
5. Mitrophanov, A. Yu.: Stability and exponential convergence of continuous-time Markov chains. J. Appl. Probab., 40, 970–979 (2003)
6. Mitrophanov, A. Yu.: The spectral gap and perturbation bounds for reversible continuous-time Markov chains. J. Appl. Probab. 41, 1219–1222 (2004)
7. Nelson, R., Towsley, D., & Tantawi, A. N.: Performance analysis of parallel processing systems. IEEE Transactions on software engineering, 14(4), 532–540 (1988)
8. Zeifman, A. I.: Some properties of a system with losses in the case of variable rates. Automation and Remote Control, 50:1, 82-87 (1989)
9. Zeifman, A. I.: Upper and lower bounds on the rate of convergence for nonhomogeneous birth and death processes. Stoch. Proc. Appl., 59, 157–173 (1995)
10. Zeifman, A., Satin, Y., Panfilova, T. Limiting characteristics for finite birthdeath-catastrophe processes. Mathematical biosciences, 245(1), 96–102 (2013)
11. Zeifman, A., Satin, Ya., Korolev, V., Shorgin, S.: On truncations for weakly ergodic inhomogeneous birth and death processes. International Journal of Applied Mathematics and Computer Science. 24, 503–518 (2014)
12. Zeifman, A., Korotysheva, A. , Korolev, V., Satin, Y., Bening, V.: Perturbation bounds and truncations for a class of Markovian queues. Queueing Systems, 76, 205–221 (2014)
13. Zeifman, A. I., Korolev, V. Y.: On perturbation bounds for continuous-time Markov chains. Statistics & Probability Letters, 88, 66–72 (2014)
14. Zeifman, A. I., Korolev, V. Y.: Two-sided bounds on the rate of convergence for continuous-time finite inhomogeneous Markov chains. Statistics & Probability Letters, 103, 30–36 (2015)
15. Zeifman, A., Korotysheva, A., Satin, Y. , Razumchik, R., Korolev, V., Kiseleva, K.: Bounds on the rate on convergence and perturbations for some classes of Markovian queues. Preprint (2016)

A random tandem network with queues modeled as Markov birth-death processes*

Virginia Giorno and Amelia G. Nobile

Dipartimento di Informatica, Università di Salerno,
Via Giovanni Paolo II, n. 132, 84084 Fisciano (SA), Italy,
{giorno,nobile}@unisa.it

Abstract

Stochastic queueing networks are successfully used to describe a variety of different real systems, such as telecommunications systems, computer systems, call centers and manufacturing systems (cf., for instance, [1]–[12]). In an open network, there is at least one node through which the customers enter the network and at least one node through which the customers leave the network. To define an open queueing network, must be specified the external arrival process, the routing of customers among the different queues in the network, the number of serves at each queue, the service time distribution and the service discipline at each queue. In particular, a tandem network consists of some finite number of queueing systems in series. For instance, in manufacturing systems, a serial production line consists of machines and buffers; between any two subsequent machines there is a buffer and between any two subsequent buffers there is a machine.

In this paper, we consider a tandem network consisting of an arbitrary but finite number R of queueing systems, where R is a discrete random variable that assume values $1, 2, \ldots, m$ according suitable probability distributions. The component C_j ($j \leq m$) of the tandem network consists of an infinite buffer space to hold the customers waiting and of a service center with a single server and it is modeled via a birth-death process. For fixed $R = r$, the tandem network satisfies the following assumptions: *(i)* there is only one job class in the network; *(ii)* the overall number of jobs in the network is unlimited; *(iii)* the customers arrive to the first queueing system from an external source according to a Poisson process of rate λ; *(iv)* the service discipline at all nodes is FCFS (first-come, first-served) and there is a single server available to each node; *(v)* the service times at C_j are exponentially distributed with mean $[\mu_j(n_j)]^{-1}$ when there are n_j customers in C_j just before the departure of a customer. Figure 1 shows a tandem network that consists of the components $C_1, C_2, \ldots, C_r$ ($r \leq m$). The individual components C_j can be modeled in a variety of different ways and also the network can be constituted by very different type of systems to be mixed together in the same tandem network.

* (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems")

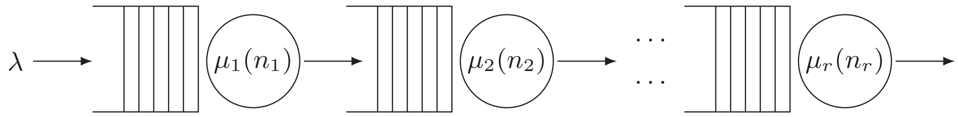


Fig. 1. Tandem queueing network with state dependent service rates.

The network in Figure 1 is an extension of the Jackson tandem network and the system's state probability distribution can be still expressed as a product-form solution. Denoting by $(N_1, N_2, \ldots N_R)$ the vector that describes the state of the tandem network in equilibrium regime, we analyze the distribution of the total number of customers $N = N_1 + N_2 + \ldots + N_R$ in the network both for different choices of the birth-death processes making up the network, that for suitable probability distributions of the random variable R. Finally, performance measures of the tandem networks are obtained and compared.

References

1. Baskett F., Chandy K.M., Muntz R., Palacios F.G.: Open, closed, and mixed networks of queues with different classes of customers. J. of the ACM 22, no. 2, 248–260 (1975)
2. Bar-Lev S.K., Blanc H., Boxma O., Janssen G., Perry D.: Tandem queues with impatient customers for blood screening procedures. Methodol Comput Appl Probab 15, 423–451 (2013)
3. Bose S. K.: An Introduction to Queueing Systems. Springer Science+Business Media, New York (2002)
4. Chen H., Yao D.D.: Fundamentals of Queueing Networks. Performance, Asymptotics, and Optimization, Springer Science+Business Media, New York (2001)
5. Filipowicz B., Kwiecień J.: Queueing systems and networks. Models and applications. Bulletin of the Polish Academy of Sciences, Technical Sciences 56, no. 4, 379–390 (2008)
6. Jackson J.R.: Networks of waiting lines. Operations Research 5, no. 4, 518–521 (1957)
7. Kim C., Dudin A., Dudina O., Dudin S.: Tandem queueing system with infinite and finite intermediate buffers and generalized phase-type service time distribution. European Journal of Operation Research 235, 170–179 (2014)
8. Kobayashi H., Konheim A.G.: Queueing models for computer communications system analysis. IEEE Transactions on Communications 25, no. 1, 2 –29 (1977)
9. Lemoine A.J.: State-of-the-art – Networks of queues – A survey of equilibrium analysis. Management Science 24, no. 4, 464–481 (1997)
10. Serfozo R.: Introduction to Stochastic Networks, Springer Science+Business Media, New York (1999)
11. Williams R.J.: Stochastic processing networks. Annual Review of Statistics and Its Application 3, 323–345 (2016)
12. Wu K., McGinnis L.: Performance evaluation for general queueing networks in manufacturing systems: Characterizing the trade-off between queue time and utilization. European Journal of Operational Research 221, 328–339 (2012)

Precise Parameter Synthesis for Stochastic Petri Nets with Interval Rate Parameters ⋆

Milan Češka jr.[1], Milan Češka[1], and Nicola Paoletti[2]

[1] Faculty of Information Technology, Brno University of Technology, Czech Republic
[2] Department of Computer Science, Stony Brook University, USA

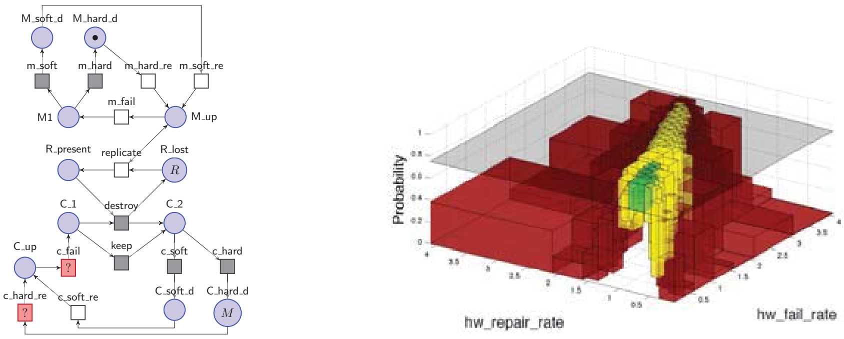
Extended Abstract

Various extensions of Stochastic Petri Nets (SPNs), e.g. generalised SPNs [6], have been introduced to model complex and concurrent systems in many areas of science. In biochemistry, quantitative models of genetic networks can be expressed as SPNs [4]. In engineering, generalised SPNs are used to study various reliability and performance aspects of manufacturing processes, computer networks and communication protocols [1, 2]. Assuming certain restrictions on the structure of SPNs, their dynamics can be described using a finite-state continuous-time Markov chains (CTMCs) [6]. This allows modellers and designers to perform quantitative analysis and verification of SPSs using well-known formal methods for CTMCs (see e.g. [5]).

Traditionally, formal analysis of SPNs assumes that transition rates are known a priori. This is often not the case and one has to consider ranges of parameter values instead, for example, when the parameters result from imprecise measurements, or when designers are interested in finding parameter values such that the model fulfils a given specification. In this paper, we tackle the parameter synthesis problem for SPNs, described as follows:
"Given a time-bounded temporal property describing the required behaviour and a parametric SPN (pSPN) whose transition rates are functions of the parameters, automatically find parameter values such that the satisfaction probability of the formula meets a given threshold, is maximised, or minimised".

Importantly, this problem requires effective reasoning about uncountable sets of SPNs, arising from the presence of continuous parameter ranges. In particular, we focus on pSPNs representing uncountable sets of extended SPNs. We show that, under this mild restriction, we can describe the dynamics of a pSPN by a parametric CTMC (pCTMC) [3]. The parameter synthesis problem for pSPNs can be then reduced to the equivalent problem for pCTMCs and thus, we can employ existing synthesis algorithms that combine computation of probability bounds for pCTMCs with iterative parameter space refinement in order to provide arbitrarily precise answers. We further demonstrate that pSPNs provide an adequate modelling formalism for designing complex systems where parameters of the environment (e.g., request inter-arrival times and component failure

⋆ This work has been supported by the Czech Grant Agency grant No. GA-24707Y and the IT4Innovations Excellence in Science project No. LQ1602.



(a) pSPN for the Google File System [2] (b) Synthesised parameters

Fig. 1: Example of pSPN synthesis. Left: red boxes with question marks indicate parametric rates. Right: parameters satisfying the property (green), not satisfying (red), and uncertain (yellow).

rates) and of implemented software (e.g. service rates) can be meaningfully expressed as intervals. We also show that sSPNs can be used for *in silico* analysis of stochastic biochemical systems with uncertain kinetic parameters.

Figure 1 (left) illustrates a pSPN describing the model of Google File System [2] with parameters affecting the failure rate of chunk servers and their repair rate from a hardware failure. The right part illustrates the outcome of a synthesis experiment, namely the parameter regions for which the probability of reaching a certain service level within a given time interval is above 75%.

The main contribution of the paper can be summarised as follows:

- formulation of the parameter synthesis problem for SPNs using pSPNs
- automatic translation of pSPNs into pCTMCs allowing to exploit existing synthesis algorithms
- two case studies from the biological and engineering domains, through which we demonstrate the effectiveness of parameter synthesis in the automated design and parametric analysis of pSPNs.

References

1. Robert Y Al-Jaar and Alan A Desrochers. Performance evaluation of automated manufacturing systems using generalized stochastic petri nets. *IEEE Transactions on Robotics and Automation*, 6(6):621–639, 1990.
2. Christel Baier et al. Model checking for performability. *Mathematical Structures in Computer Science*, 23(04):751–795, 2013.
3. Milan Češka et al. Precise parameter synthesis for stochastic biochemical systems. *Acta Informatica*, pages 1–35, 2016.
4. Peter JE Goss and Jean Peccoud. Quantitative modeling of stochastic systems in molecular biology by using stochastic petri nets. *Proceedings of the National Academy of Sciences*, 95(12):6750–6755, 1998.
5. Marta Kwiatkowska, Gethin Norman, and David Parker. Stochastic model checking. In *Formal methods for performance evaluation*, pages 220–270. Springer, 2007.
6. Marco Ajmone Marsan et al. *Modelling with generalized stochastic Petri nets*. John Wiley & Sons, Inc., 1994.

Estimating the effect of a therapy in a Gompertz-type diffusion process ⋆

Giuseppina Albano[1], Virginia Giorno[2],
Patricia Román-Román[3], Francisco Torres-Ruiz[3]

[1] Dip. di Scienze Economiche e Statistiche, Università di Salerno, Italy
pialbano@unisa.it
[2] Dip. di Informatica, Università di Salerno, Italy
giorno@unisa.it
[3] Dep. de Estadística e Investigación Operativa, Universidad de Granada, Spain
{proman,fdeasis}@ugr.es

Abstract

Dynamic models to describe growth phenomena play an important role in several fields such as economy, biology, medicine, ecology. For this reason numerous efforts are oriented to the development of progressively more sophisticated mathematical models for the description of a particular type of behavior. In this context, stochastic models seems to be able to provide realistic explanation of biological variables. In particular, stochastic processes characterized by sigmoidal sample-paths capture main features of several growth phenomena such as carrying capacity, i.e. the maximum population size of the species that the environment can sustain indefinitely.

We consider a diffusion model based on a Gompertz deterministic growth characterized by a sigmoidal shape with a carrying capacity depending on the initial size of the population. Specifically, let $\{X(t),\ t \geq t_0\}$ be a time non-homogeneous diffusion process defined in $\mathbb{R}^+$ characterized by the following stochastic differential equation:

$$dX(t) = me^{-\beta t}X(t)dt + \sigma X(t)dW(t), \qquad X(t_0) = x_0 \ a.s., \tag{1}$$

where m, β are positive constants representing the natural growth parameters, $\sigma > 0$ describing the width of random fluctuations and $W(t)$ is a standard Wiener process.

In real-life situations, intrinsic growth rates of the population can be modify by means of exogenous terms generally depending on time. Examples of such situations could be therapeutic treatments in tumor growth (see for instance [4]) or suitable food treatments in growth of animals (see [2]). In order to model such situations, we modify the drift of $X(t)$ by introducing a time dependent function $C(t)$ to model the effect of an exogenous factor (namely *therapy*), obtaining the stochastic process $X^C(t)$ such that

$$dX^C(t) = [m - C(t)]e^{-\beta t}X(t)dt + \sigma X(t)dW(t), \qquad X^C(t_0) = x_0 \ a.s.. \tag{2}$$

⋆ (Workshop “Stochastic Models and Applications to Natural, Social and Technical Systems.”)

Generally, in experimental studies the effect of a new therapy has to be tested so the term $C(t)$ is usually unknown. Further, the knowledge of such functional form is fundamental since it allows to introduce an external control to the system and to explain how the therapy acts. Moreover, the study of some problems related to the process $X^C(t)$, i.e. modeling and forecasting, requires the knowledge of $C(t)$. For these reasons, the functional form of $C(t)$ has to be estimated.

In this paper, firstly we analyze some characteristics of the considered diffusion processes, $X^C(t)$ and $X(t)$; secondly, we propose a two step estimation procedure when data from a control group and from one or more treated groups are available. In the first step from the control group, modeled by means of (1), the parameters m, β and σ are estimated by maximum likelihood method (see [7] and [8]). In the second step the function $C(t)$ is estimated making use of some relations linking the process $X(t)$ describing a control group (untreated) and $X^C(t)$ modeling the treated group. The idea is to take the model $X(t)$ as a starting point and then to use the information provided by the treated group to try approximate the function $C(t)$. Therefore, after estimating the parameters of $X(t)$, $C(t)$ is estimated by the trajectories of the treated groups and by suitable relations between the two models.

Finally, in order to evaluate the goodness of the proposed procedure a simulation study is presented.

References

1. Albano G., Giorno V., Román-Román P., Torres-Ruiz F.: On the first exit time problem for a Gompertz diffusion. In Cybernetics and Systems 2010 (Trappl R., ed.). EMCSR 2010. Austrian Society for Cybernetics Studies, Vienna, 175-180, ISBN 978-3-85206-178-8 (2010)
2. Albano G., Giorno V., Román-Román P., Torres-Ruiz F.: On the therapy effect for a stochastic Gompertz-type model. Math. Biosci. 235, 148-160 (2012)
3. Albano G., Giorno V., Román-Román P., Torres-Ruiz F.: Inferring the effect of therapy on tumors showing stochastic Gompertzian growth. J. Theor. Biol. 276, 67-77 (2011)
4. Albano G., Giorno V., Román-Román P., Román-Román S., Torres-Ruiz F.: Estimating and determining the effect of a therapy on tumor dynamics by means of a modified Gompertz diffusion process. J. Theor. Biol. 364, 206-219 (2015)
5. Blasco A., Piles M., Varona L.: A Bayesian analysis of the effect of selection for growth rate on growth curves in rabbits. Genet. Select. Evol. 35, 21-41 (2003)
6. Di Crescenzo A., Spina S.: Analysis of a growth model inspired by Gompertz and Korf laws, and an analogous birth-death process Math. Biosci. (to appear)
7. Gutiérrez-Jáimez R., Román-Román P., Romero D., Serrano J.J., Torres-Ruiz F.: A new Gompertz-type diffusion process with application to random growth. Math. Biosci. 208, 147-165 (2007)
8. Román-Román P., Romero D., Rubio M.A., Torres-Ruiz F.: Estimating the parameters of a Gompertz-type diffusion process by means of simulated annealing. Appl. Math. Comput. 218, 5121-5131 (2012)

Tsallis and Kaniadakis Entropy Measures for Risk Neutral Densities

Muhammad Sheraz[a,], Vasile Preda[b,c], Silvia Dedu[d]

[a,e] Department of Mathematical Sciences & Department of Economics and Finance,
Institute of Business Administration Karachi, Pakistan, msheraz@iba.edu.pk
[b] Faculty of Mathematics and Computer Science, University of Bucharest, Bucharest, Romania.
[c] National Institute for Economic Research, Bucharest, Romania.
[d] Department of Applied Mathematics, Bucharest University of Economic Studies, Bucharest, Romania.
[e] Ningbo University, Ningbo, China.

Abstract

Concepts of Econophysics are usually used to solve problems related to uncertainty and nonlinear dynamics. In the theory of option pricing the risk neutral probabilities plays very important role. The application of entropy in finance can be regarded as the extension of both information entropy and the probability entropy. It can be an important tool in various financial methods such as measure of risk, portfolio selection, option pricing and asset pricing. The present structure of stock option pricing is based on Black and Scholes model, but the model has some restricted assumptions and contradicts with modern research in financial literature.

The Black-Scholes model is governed by Geometric Brownian Motion (GBM) based on stochastic calculus. The current technology of stock option pricing (Black-Scholes model) depends on two factors (a) No arbitrage which implies the universe of risk-neutral probabilities and (b) Parameterization of risk-neutral probability by a reasonable stochastic process. This implies risk-neutral probabilities are vital in this framework.

The Entropy Pricing Theory (EPT) of Les Gulko is an alternative approach of constructing risk-neutral probabilities without depending on stochastic calculus. Gulko applied EPT for pricing stock options and introduced an alternative framework of Black-Scholes model for pricing European stock option.

The concept of entropy plays crucial role to extract universal features of a system from its microscopic details. In statistical mechanics the entropy is defined as the logarithm of total number of microstates multiplied by a constant coefficient or alternatively it is written in terms of the probability to occupy the microstates.

The Shannon entropy can be used in particular manners to evaluate the entropy of probability density distribution around some points, but on other hand if we consider specific events for example deviation from the mean or any sudden news in the case of stock market. At this point one needs additional information and this concept of entropy can be generalized. In 1988 Tsallis introduced a new definition for entropy which successfully describes the statistical features of complex systems. Some other examples of entropy measures that depend on power of the probability were introduced as generalization of the Shannon entropy, include Kaniadakis, Renyi, Ubriaco and Shafee entropy measures.

In finance, particularly pricing derivatives the estimation of correct Risk-Neutral-Density (RND) implied by the option prices, remains one of the most important problem. Most of the theoretical and empirical studies, which are aimed to improve the performance of the BS model, have focused on recovering the correct RND implied by option prices.

In this article we use Tsallis and Kaniadakis entropy measures to find the risk-neutral densities using the framework of EPT for stock options. We introduce the weighted cases for both Tsalllis and Kanidakis. In Section 2 we present the introduction of EPT and formulation of our problems, and then we further develop the structure to obtain our new results. In Section 3 we present our results using Tsallis, Weighted Tsallis and Expected Utility- Weighted Tsallis (EU-WTE) to get risk-neutral density of stock options. In Section 4 we present our results by using Kaniadakis, Weighted Kaniadakis and the Expected Utility-Weighted Kaniadakis Entropy (EU-WKE) framework for the underlying entropy maximization problems. In section 5 we calculate the European Call and Put in this framework. Section 6 concludes our results.

Acknowledgements The work was partially supported by Ningbo Natural Science Foundation (No.2016A610077), and K.C. Wong Fund of Ningbo University.

References

1. Black, F.; Scholes, M. The pricing of options and corporate liabilities, Journal of Political Economy. 1973, 81,637-659.
2. Borwein, J. ; Choksi, R. ; Maréchal, P. Probability distributions of assets inferred from option prices via the principle of maximum entropy. Journal of Society for Industrial and Applied Mathematics. 2003, 14, 464-478.
3. Bellis, M. ; Guiasu, S. A quantitative-qualitative measure of information in cybernetic systems, IEEE Transformation Information Theory.1968, 14, 593.
4. Casquilho, J. ;Neves, M. ; Rego. F. Extensos da funcao de Shannon e equilibrio de proporcoes-uma aplicacao ao mosaico de paisagem, Anais do Instituto Superior de Agronomia. 1997, 46, 77-99.
5. Cressie, N. ; Richardson, S. ; Jaussent, I. Ecological bias: Use of maximum entropy approximations, ANZ Journal of Statistics. 2004,46(2), 233-255.
6. Gulko, L. Dart Boards and Asset Prices: Introducing the Entropy Pricing Theory. 1997, Chapter 14 in Advances in Econometrics. T.B. Fomby and R.C, Hill eds, JAI press, Greenwich, CT.
7. Gulko, L. The Entropy Theory of Bond Option Pricing,Working Paper, 1995, Yale School of Management, October, New Haven, CT.
8. Guiasu, S. Weighted entropy, Reports on Mathematical Physics. 1971, 2(3), 165-179.
9. Knight, F. Risk, uncertainty and pro.t. Reprint of Scarce Texts in Economic and Political Science, 1921,16.
10. Luenberger, D.G. Optimization by vector space methods, 1969,Wiley, New York.
11. Preda,V. ; Sheraz, M. Risk-Neutral Densities in Entropy Theory of Stock Options using Lambert Function and a New Approach, Proceedings of the Romanian Academy, 16 (1), 20-27, 2015.
12. Preda, V. ; Dedu, S. & Sheraz, M. New measure selection for Hunt and Devolder.s semi-Markov regime switching interest rate model , Physica A. 2014, 407, 350-359.
13. Renyi, A. On measures of entropy and information, In Proceedings of the 4th Berkely Sympodium on Mathematics of Statistics and Probability. 1961, 1, 547-561.
14. Rompolis, L.S. Retrieving risk neutral densities from European option prices based on the principle of maximum entropy. Journal of Empirical Finance. 2010, 17, 918-937.
15. Shanon, C.E. ;W. Weaver. The Mathematical theory of communication,1964, The University of Illinois Press Urbana.
16. Shafee, F. Lambert function and a new non-extensive form of entropy, Journal of Applied Mathematics. 2007, 72, 785-800.
17. Sheraz, M. ; Silvia Dedu, Vasile Preda, Entropy Measures for Assessing Volatile Markets, Procedia Economics and Finance , Vol 22, 655-662, 2015. Elsevier
18. Tsallis, C. Possible generalization of Boltzmann-Gibbs statistics, Journal of Statistical Physics.1988, 52, 479-487.
19. Trivellato, B. Deformed exponentials and applications to finance, En-tropy.2013, 15, 34-71-3489.
20. Ubriaco, M.R. Entropies based on fractional calculus, Physics Letters A. 2009, 373, 2516-2519.
21. Guo, W.Y. Maximum entropy in option pricing: a convex-spline smoothing method. JournalofFutures-Markets.2001,21,819-832.

A note on diffusion processes with jumps and applications ⋆

Virginia Giorno[1], Serena Spina[2]

[1]Dipartimento di Informatica Università di Salerno, Fisciano (SA), Italy
[2]Dipartimento di Matematica, Università di Salerno, Fisciano (SA), Italy
{giorno,sspina}@unisa.it

Abstract

Stochastic processes with jumps play a relevant role in many fields of applications. For example, in [2] birth-and-death processes with jumps are analyzed as queuing models with catastrophes, in [1], [5], [6], diffusion processes with jumps are studied in order to model an intermittent treatment for tumor diseases, in [3] a non-homogeneous Ornstein-Uhlenbeck with jumps is considered in relation to neuronal activity. In these contexts, a jump is a random event that changes the state of the process leading it to another random state from which the dynamics restarts with the same or different law. We consider diffusion processes and we assume that jumps occur at the random times chosen according a fixed probability density.

Let $\{\widetilde{X}_k(t),\, t \geq t_0 \geq 0\}$ $(k = 0, 1, \dots)$ be a diffusion stochastic process. According to [4], we construct the stochastic process with random jumps $X(t)$ as follows. Starting from the initial state $\rho_0 = x_0$ at time t_0, the process $X(t)$ evolves according to the process $\widetilde{X}_0(t)$ until a random jump occurs that shifts the process to a random state ρ_1. From here, $X(t)$ restarts according to $\widetilde{X}_1(t)$ until another jump occurs resetting the process to ρ_2 and so on. In general, the effect of the k-th jump $(k = 1, 2, \dots)$ is to shift the state of $X(t)$ in a certain level ρ_k, randomly chosen according to a probability density function (pdf) $\phi_k(\cdot)$. Then, the process evolves like $\widetilde{X}_k(t)$, until a new jump occurs.

$X(t)$ consists of independent cycles $\mathcal{I}_1$, $\mathcal{I}_2$ ..., whose durations are independent random variables I_1, $I_2, \dots$, representing the time intervals between two consecutive jumps. For $k = 1, 2, \dots$, the random variable I_k is distributed with pdf $\psi_k(\cdot)$. We denote by $\Theta_1, \Theta_2, \dots$ the times in which the jumps occur. We set $\Theta_0 = t_0$ that corresponds the initial time and for $k = 1, 2, \dots$, let $\gamma_k(\tau)$ be the pdf of the random variable Θ_k. The variables I_k and Θ_k are related, indeed $\Theta_1 = I_1$ and for $k > 1$ it results: $\Theta_k = I_1 + I_2 + \dots I_k$. Hence, the pdf $\gamma_k(\cdot)$ of Θ_k and the pdf $\psi_k(\cdot)$ of I_k are related, indeed $\gamma_1(t) = \psi_1(t)$ and $\gamma_k(t) = \psi_1(t) * \psi_2(t) * \cdots * \psi_k(t)$, where "$*$" denotes the convolution operator. Furthermore, $\rho_0 = x_0$ and ρ_k is the return state in correspondence of the k-th jump, for $k \geq 1$. In Fig. 1 a sample path of $X(t)$ is shown.

In the paper we study $X(t)$ by analyzing the transition pdf, its moments and the first passage time problem for $X(t)$ through constant boundaries. We

⋆ (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems.")

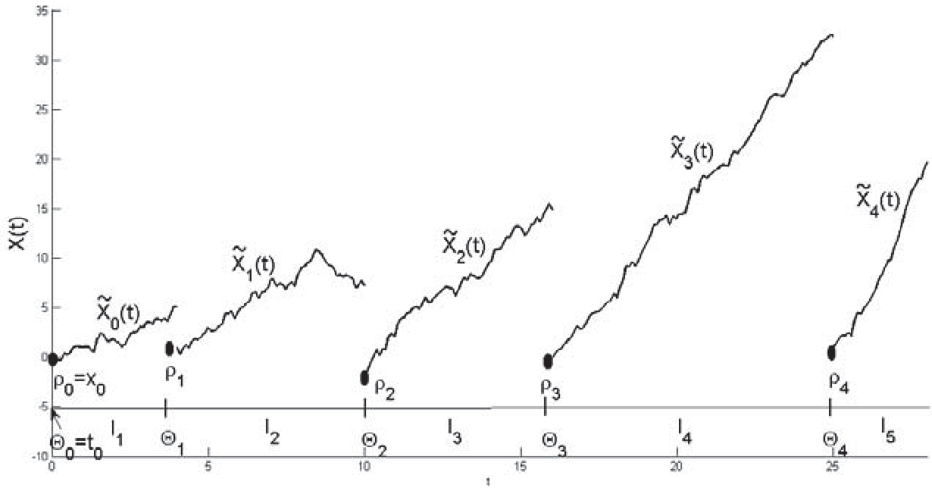


Fig. 1. A sample path of the diffusion process with jumps $X(t)$.

consider some particular cases when the inter-jumps I_k are deterministic or exponentially distributed. Moreover, the case of deterministic return states is esaminated.

Finally, we apply the obtained results to diffusion processes of interest in the applications.

References

1. Giorno V., Spina S.: A Stochastic Gompertz Model with Jumps for an Intermittent Treatment in Cancer Growth. Lect. Notes Comput. Sc. Vol. 8111: 61-68 (2013)
2. Giorno V., Nobile A.G. , Spina S.: A note on time non-homogeneous adaptive queue with catastrophes, Appl. Math. Comput., 245: 220234 (2014)
3. Giorno V., Spina S.: On the return process with refractoriness for non-homogeneous Ornstein -Uhlenbeck neuronal model. Mathematical Biosciences and Engineering vol. 11, no.2: 285-302 (2014)
4. Giorno V., Spina S.: Some remarks on stochastic diffusion processes with jumps. Lecture Notes of Seminario Interdisciplinare di Matematica Vol. 12: 161-168 (2015)
5. Giorno V., Román-Román P., Spina S., Torres-Ruiz F.: Estimating a non-homogeneous Gompertz process with jumps as model of tumor dynamics. To appear in Computational Statistics and Data Analysis (2016)
6. Spina S., Giorno V., Román-Román P., Torres-Ruiz F.: A Stochastic Model of Cancer Growth Subject to an Intermittent Treatment with Combined Effects: Reduction of Tumor Size and Rise of Growth Rate. Bulletin of Mathematical Biology DOI 10.1007/s11538-014-0026-8 (2014)

Some remarks on the mean of the running maximum of integrated Gauss-Markov processes and their first-passage times.

Marco Abundo and Mario Abundo

Tor Vergata University, Rome, Italy
marco.abundo@gmail.com,abundo@mat.uniroma2.it

Abstract. For a continuous stochastic process $X(t)$ with $X(0) = 0$, let us consider the running maximum process $S(t) := \max_{s\in[0,t]} X(s)$; it was found in [6] a connection between its mean $a(t) = E[S(t)]$ and that of the first-passage time (FPT) τ_r of X through a threshold $r > 0$. Precisely, assuming that $a(t)$ is strictly increasing (i.e. the inverse a^{-1} exists), it was shown that, for any non-decreasing function $g : [0, +\infty) \longrightarrow [0, +\infty)$, it results:

$$E\left[g(\tau_r)\right] \geq \int_0^1 g(a^{-1}(rt))dt, \tag{1}$$

and that this bound is sharp. Of course, while the right-hand side of (1) is finite for any bounded and sufficiently regular g, the left-hand side can be infinity. In particular, for any integer n, one gets:

$$E\left[(\tau_r)^n\right] \geq \int_0^1 \left(a^{-1}(rt)\right)^n dt. \tag{2}$$

Notice that the exact calculation of the moments of the FPT is not always possible, while the mean of the maximal process is available, or estimable by empirical observations, in many cases (see e.g. the discussion in [6]); thus, inequality (2) is very useful, since it provides lower bounds to the moments of the FPT of X through the level boundary $r > 0$, in terms of the mean of the running maximum process.
In this paper, motivated by the result of [6], we aim to calculate the function $a(t) = E\left[\max_{s\in[0,t]} X(s)\right]$ for integrated Gauss-Markov processes, in particular, for integrated Brownian motion and integrated Ornstein-Uhlenbeck process. In the cases when it is possible to calculate exactly $E\left[(\tau_r)^n\right]$, we compare it with its lower bound given by (2).
Actually, the interest in the study of integrated Gauss-Markov processes relies on the fact that they have many important applications in Biology (e.g. in the framework of diffusion models for neural activity), in Queueing Theory, in Economy, Mathematical Finance, and other applied sciences (see e.g. the discussion in [1], [2]).
Now, we recall the definition of Gauss-Markov process, and its integrated process. Let $m(t)$, $h_1(t)$, $h_2(t)$ be continuous functions of $t \geq 0$, which are C^1 in $(0, +\infty)$, and such that $h_2(t) \neq 0$ and $\rho(t) = h_1(t)/h_2(t)$ is a non-negative, differentiable and increasing function, with $\rho(0) = 0$. If $B(t) = B_t$ denotes standard Brownian motion (BM), then for $t \geq 0$:

$$Y(t) = m(t) + h_2(t)B(\rho(t)), \tag{3}$$

is a continuous Gauss-Markov process with mean $m(t)$ and covariance $c(s,t) = h_1(s)h_2(t)$, for $0 \leq s \leq t$.
Besides BM, a noteworthy case of Gauss-Markov process is the Ornstein-Uhlenbeck (OU) process, and in fact any continuous Gauss-Markov process can be represented in terms of a OU process (see e.g. [9]).
For a continuous Gauss-Markov process Y, its integrated process, starting from $X(0)$ is defined by $X(t) = X(0) + \int_0^t Y(s)ds$.
In this paper, we make use of the results of [1], in which, assuming $Y(0) = 0$, we have studied the distribution of the FPT of X through a boundary r, with the conditions that $X(0) = x$, that is:

$$\tau_r(x) := \inf\{t > 0 : X(t) = r | X(0) = x\}; \tag{4}$$

moreover, for $r_2 > r_1$ and $x \in (r_1, r_2)$, in [1] we have studied the distribution of the first-exit time (FET) of X from the interval (r_1, r_2), with the conditions that $X(0) = x$, that is:

$$\tau_{r_1,r_2}(x) := \inf\{t > 0 : X(t) \notin (r_1, r_2) | X(0) = x\}. \tag{5}$$

Notice that the distribution of τ_r is related to that of the running maximum $S(t) = \max_{s\in[0,t]} X(s)$, since $P(\tau_r \leq t) = P(S(t) \geq r)$; as for the distribution of τ_{r_1,r_2}, one has $\tau_{r_1,r_2} = \min\{\tau_{r_1}, \tau_{r_2}\}$, with $P(\tau_{r_2} \leq t) = P(S(t) \geq r_2)$ and $P(\tau_{r_1} \leq t) = P(\min_{s\in[0,t]} X(s) \leq r_1)$.

References

[1] Abundo, M., 2015. On the first-passage time of an integrated Gauss-Markov process. Scientiae Mathematicae Japonicae Online e-2015, 28, 1–14.

[2] Abundo, M., 2013. On the representation of an integrated Gauss-Markov process. Scientiae Mathematicae Japonicae Online e-2013, 719-723

[3] Abundo, M., 2012. An inverse first-passage problem for one-dimensional diffusions with random starting point. Statistics and Probability Letters 82 (1), 7–14.

[4] Abundo, M., 2002. Some conditional crossing results of Brownian motion over a piecewise-linear boundary. Statistics and Probability Letters 58(2), 131-145.

[5] Beghin, L., Orsingher, E., 1999. On the maximum of the generalized Brownian bridge. Lithuanian Mathematical Journal 39(2), 157–167.

[6] Brown, M., de la Pena, V. H. , Klass, M., Sit, T., 2016. On an approach to boundary crossing by stochastic processes. Stochastic Processes and their Applications (in press) http//dx.doi.org/10.1016/j.spa.2016.04.027

[7] Brown, M., de la Pena, V. H. , Klass, M., Sit, T., 2015. From boundary crossing of non-random functions to boundary crossing of stochastic processes. Probab. Engrg. Inform. Sci. 29, 345–359, doi:10.1017/S0269964815000030

[8] Klebaner, F.C., 2005. Introduction to Stochastic Calculus with Applications. Second Edition. Imperial College Press, London.

[9] Nobile, A.G., Pirozzi, E., Ricciardi, L.M. , 2008. Asymptotics and evaluations of FPT densities through varying boundaries for Gauss-Markov processes. Sci. Math. Jpn. 67, (2), 241–266.

On the comparison of means of distorted random variables

Antonio Di Crescenzo[1], Barbara Martinucci[1], and Julio Mulero[2]

(1) Dipartimento di Matematica, Università di Salerno, Italy
adicrescenzo@unisa.it,bmartinucci@unisa.it
(2) Departamento de Matemáticas, Universidad de Alicante, Spain
julio.mulero@ua.es

A probabilistic generalization of the Taylor's theorem was proposed and studied by Massey and Whitt [6] and Lin [5], showing that for a nonnegative random variable X and a suitable function f one has

$$\mathbb{E}[f(t+X)] = \sum_{k=0}^{n-1} \mathbb{E}[X^k] \frac{f^{(k)}(t)}{k!} + \mathbb{E}[f^{(n)}(t+X_{\mathrm{e}})] \frac{f^{(n)}(t)}{n!},$$

where X_{e} is a random variable possessing the equilibrium distribution of X. This result was employed by Di Crescenzo [2] in order to obtain the following probabilistic mean value theorem:

$$\mathbb{E}[g(Y)] - \mathbb{E}[g(X)] = \mathbb{E}[g'(Z)][\mathbb{E}(Y) - \mathbb{E}(X)],$$

valid for nonnegative and stochastically ordered random variables Y and Y, where the random variable Z is a generalization of X_{e}, and has density function

$$\frac{\mathbb{P}(Z \in dx)}{dx} = \frac{\mathbb{P}(Y > x) - \mathbb{P}(X > x)}{\mathbb{E}(Y) - \mathbb{E}(X)}.$$

Various related results have been exploited recently, such as the fractional probabilistic Taylor's and mean value theorems (see Di Crescenzo and Meoli [4]), and a quantile-based version of the probabilistic mean value theorem (see Di Crescenzo *et al.* [3]). The latter result involves a distribution that generalizes the Lorenz curve, and allows the construction of new distributions with support $(0, 1)$. Specifically, let X be an absolutely continuous random variable with finite non-zero mean, with distribution function $F(x) = \mathbb{P}(X \leq x)$, with quantile function given by $Q(u) = \inf\{x \in \mathbb{R} : F(x) \geq u\}$, $0 < u < 1$, such that $Q(0) = 0$, and with quantile density $q(u) = Q'(u)$, $0 < u < 1$. Then, if $g : (0, 1) \to \mathbb{R}$ is n-times differentiable and $g^{(n)} \cdot Q$ is integrable on $(0, 1)$ for any $n \geq 1$, then

$$\begin{aligned}\mathbb{E}[\{g(1) - g(U)\}\, q(U)] = &\sum_{k=1}^{n-1} \frac{1}{k!} \mathbb{E}\left[g^{(k)}(U)(1-U)^k q(U)\right] \\ &+ \frac{1}{(n-1)!} \mathbb{E}\left[g^{(n)}(X^L)(1-X^L)^{n-1}\right] \mathbb{E}[X],\end{aligned}$$

where U is uniformly distributed in $(0, 1)$, and where X^L is a random variable with probability density function $\mathbb{P}(X^L \in du)/du = Q(u)/\mathbb{E}[X]$, $0 < u < 1$.

Stimulated by the above mentioned results, we construct new relationships for the comparison of means values of distorted random variables. For the role of distortion functions in applied contexts involving risk theory and mathematical economics, we recall for instance the recent contributions by Balbás *et al.* [1] and Sordo *et al.* [7], [8]. Our results are based on the quantile-based version of the probabilistic mean value theorem, and deserve interest in utility theory. They can be applied also for assessing stochastic dominance among risks.

References

1. Balbás, A., Garrido, J., Mayoral, S. 2009. Properties of distortion risk measures. Methodol. Comput. Appl. Probab. 11, 385–399.
2. Di Crescenzo, A. 1999. A probabilistic analogue of the mean value theorem and its applications to reliability theory. J. Appl. Probab. 36, 706–719.
3. Di Crescenzo, A., Martinucci, B., Mulero, J. 2016. A quantile-based probabilistic mean value theorem. Probab. Engrg. Inform. Sci. 30, 261–280.
4. Di Crescenzo, A., Meoli, A. 2016. On the fractional probabilistic Taylor's and mean value theorems. Fract. Calc. Appl. Anal. 19, 921–939.
5. Lin, G.D. 1994. On a probabilistic generalization of Taylor's theorem. Statist. Prob. Lett. 19, 239–243.
6. Massey, W.A., Whitt, W. 1993. A probabilistic generalization of Taylor's theorem. Statist. Prob. Lett. 16, 51–54.
7. Sordo, M.A., Navarro, J., Sarabia, J.M. 2014. Distorted Lorenz curves: models and comparisons. Soc. Choice Welf. 42, 761–780.
8. Sordo, M.A., Suárez-Llorens, A., Bello, A.J. 2015. Comparison of conditional distributions in portfolios of dependent risks. Insurance Math. Econom. 61, 62–69.

A General Solution Approach for the Location Routing Problem

Viktoria A. Hauder[1,2], Johannes Karder[1,3], Andreas Beham[1,3], and Michael Affenzeller[1,3]

[1] Heuristic and Evolutionary Algorithms Laboratory
School of Informatics, Communications and Media
University of Applied Sciences Upper Austria, Hagenberg Campus, Austria
{viktoria.hauder,johannes.karder,andreas.beham, michael.affenzeller}@fh-hagenberg.com

[2] Institute for Production and Logistics Management
Johannes Kepler University Linz, Austria

[3] Institute for Formal Models and Verification
Johannes Kepler University Linz, Austria

Motivation and Literature Review. With the beginning of the fourth industrial revolution, also called industry 4.0, high adaptability and resource efficiency of organizations are becoming increasingly important [3]. Within so-called smart enterprises, which are a major reference point within industry 4.0, information should be changed in real time and all involved agents should be connected [3]. Therefore, also in the field of optimization in production and logistics, a combination of interrelated problem models is gaining growing importance [1]. With the introduction of the simultaneous optimization of more than one production and logistics optimization problem, the ability to react and respond quickly to changing external and internal influences should be improved.

One already existing combination of two logistics optimization problems is the so-called Location Routing Problem (LRP) [2, 4]. It consists of the Facility Location Problem (FLP), which is a strategic logistics optimization problem, and the Vehicle Routing Problem (VRP), an operational optimization problem. As the determination of facility locations influences routing costs to other facilities or customers, there is a codependence between the FLP and the VRP. Therefore, by combining these two optimization problems, potential synergies can be exploited [2, 4]. In the surveys of [2] and [4] about the LRP, different problem model formulations and also solution methods already exist. Concerning heuristic solutions, [2] state that there have already been successful approaches by splitting up the LRP into a FLP and a VRP, for example through the use of population-based algorithms.

However, considering the idea of integrated solution approaches in the context of industry 4.0, not only an interconnection should exist. There should rather be a continous exchange of information between problem models. As for example the utilization of production and also warehouse departments is becoming increasingly dynamic, organizations are expected to become more flexible. Decision situations regarding the temporary rental of warehouses should be supported. Therefore, a system which provides information for more than one problem instance and is supportive over time is needed. As a consequence, a methodology considering the high adaptability requirements of smart factories is developed. It is expected that limitations concerning solution quality and run time may occur.

Methodology. The approach of this paper is splitting the LRP into its basic models and solving them with existing metaheuristics. Based on this, by introducing new combination strategies, the basic models should be united again.

- *Model Splitting:* The LRP is divided into the basic models FLP and VRP. For both problem models, established solution approaches have to be found, which are generically applicable to guarantee a decision support for various problem instances appearing over time. IBM CPLEX Optimizer is used for exactly solvable parts. Moreover, existing evolutionary algorithms which are already implemented in the framework HeuristicLab [5], are applied.
- *Solution Merging:* Within a second stage, the two single solutions are merged again. By having more than one optimization run, the result of the secondly solved problem serves as an input for the first problem model. Different outcomes of both problem models are compared and the best ones are selected.

With this general approach, correlations between the splitted problems are examined. The focus is set on dependencies between the solution qualities of single problems. Influences of one result on the respective other one are analyzed.

Acknowledgments The work described in this paper was done within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532 funded by the Austrian Research Promotion Agency (FFG).

References

1. Beham, A., Fechter, J., Kommenda, M., Wagner, S., Winkler, S.M., Affenzeller, M.: Optimization strategies for integrated knapsack and traveling salesman problems. In: International Conference on Computer Aided Systems Theory. pp. 359–366. Springer (2015)
2. Drexl, M., Schneider, M.: A survey of variants and extensions of the location-routing problem. European Journal of Operational Research 241(2), 283–308 (2015)
3. MacDougall, W.: Industrie 4.0: Smart Manufacturing for the Future. Germany Trade & Invest (2014)
4. Prodhon, C., Prins, C.: A survey of recent research on location-routing problems. European Journal of Operational Research 238(1), 1–17 (2014)
5. Wagner, S., Kronberger, G., Beham, A., Kommenda, M., Scheibenpflug, A., Pitzer, E., Vonolfen, S., Kofler, M., Winkler, S., Dorfer, V., Affenzeller, M.: Advanced Methods and Applications in Computational Intelligence, Topics in Intelligent Engineering and Informatics, vol. 6, chap. Architecture and Design of the HeuristicLab Optimization Environment, pp. 197–261. Springer (2014), `http://link.springer.com/chapter/10.1007/978-3-319-01436-4_10`

A Matheuristic to solve a competitive location problem*

Dolores R. Santos-Peñate[1],
Clara Campos-Rodríguez[2], and José A. Moreno-Pérez[2]

[1] Dpto de Métodos Cuantitativos en Economía y Gestión/TIDES
Universidad de Las Palmas de Gran Canaria, Spain
dr.santos@ulpgc.es
[2] Instituto Universitario de Desarrollo Regional
Universidad de La Laguna, Spain
{ccampos,jamoreno}@ull.es

The $(r|p)$-centroid problem is a competitive location problem where two players, the leader (firm A) and the follower (firm B), enter the market sequentially and compete in providing goods or services to customers. The leader enters the market first with p facilities and seeks to minimize the maximum market share captured by a future competitor. The follower opens r facilities at the locations that maximize its market share. In this work goods are assumed to be essential, which implies that minimizing the maximum market share captured by the follower is equivalent to maximize the leader market share. The choice rule that represents the behaviour of the customers can be modeled using different functions [1]. We consider the use of a S-shaped function (see Figure 1).

The amount of demand at point c_k captured by firm B is $w_{kB} = w_k f_k(\delta_k)$ where f is a customer choice function, w_k is the demand of the customers at c_k and $\delta_k = d_{kA} - d_{kB}$ being d_{kA} and d_{kB} the distances from c_k to firms A and B. We consider the S-shaped choice functions given by:

$$f_k(\delta) = \begin{cases} 0 & \text{if } \delta \leq a_k \\ 2\left(\frac{\delta - a_k}{b_k - a_k}\right)^2 & \text{if } a_k < \delta \leq \frac{a_k+b_k}{2} \\ 1 - 2\left(\frac{\delta - b_k}{b_k - a_k}\right)^2 & \text{if } \frac{a_k+b_k}{2} < \delta \leq b_k \\ 1 & \text{if } \delta > b_k \end{cases}$$

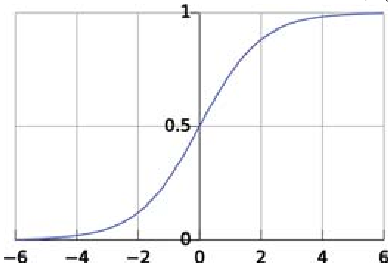
being $a_k < b_k$ two limit values corresponding to each customer point c_k.

We consider the linear formulations of the leader and follower problems and solve the leader-follower (or $(r|p)$-centroid) problem applying a similar scheme to the one described in [2, 4] but replacing the exact solution algorithm for the series of leader problems by a kernel search heuristic.

The proposed matheuristic algorithm to solve the given leader-follower problem includes the following steps:

* Partially financed by the Spanish Government, grants ECO2014-59067-P and TIN2015-70226-R

Fig. 1. A S-shape function for $f(\delta)$



Step 1 *Initialization.*

1.1 Select s feasible leader's solutions X_i, $i = 1, ..., s$. Solve the follower's problem for X_i (i.e.; the $(r|X_i)$-medianoid problem), $i = 1, ..., s$. An upper bound of W^* is $\overline{W} = \min_i S(X_i)$, where $S(X)$ is the optimal value.

1.2 Let $\mathcal{F} = \{Y_i\}_{i=1}^q$ be an initial family of good follower candidates.

Step 2 *Iterations.* Repeat, until a stop rule condition is satisfied:

2.1 Solve the leader's problem using family $\mathcal{F}$ of solutions for the follower applying the kernel search heuristic [3]. Let X be the solution obtained.

2.2 Solve the follower's problem for X. If $S(X) < \overline{W}$ then set $\overline{W} = S(X)$ and $X^* = X$. Set $\mathcal{F} = \mathcal{F} \cup \{Y(X)\}$, where $Y(X)$ is the $(r|X)$-medianoid.

The leader's problem is solved at step 2.1 using a kernel search procedure [3]:

1 Solve the LP-relaxation of the leader problem for family $\mathcal{F}$.
2 Build the initial kernel as the set of the non-zero variables. Sort the other variables and build a sequence of disjoint variable buckets with the same fixed length.
3 Solve a MILP problem on the initial kernel.
4 Repeat until a certain number of buckets have been analysed.
   a) Solve a MILP problem on the current kernel plus a bucket.
   b) Update the current kernel.

The computational results of the application of the algorithm to an example is used to show the performance of the matheuristic.

References

1. Biesinger, B., Hu, B., Raidl, G. (2016). Models and algorithms for competitive facility location problems with different customer behaviour. *Annals of Mathematics and Artificial Intellegence*, 76(1), 93-119.
2. Campos Rodríguez, C.M., Santos Peñate, D.R., Moreno Pérez, J.A. (2010). An exact procedure and LP formulations for the leader-follower location problem. *TOP*, 18(1), 97-121.
3. Guastaroba, G., Speranza, M.G. (2012). Kernel search for the capacitated facility location problem. J. Heuristics 18, 877-917.
4. Santos Peñate, D.R., Campos Rodríguez, C.M., Moreno Pérez, J.A. (2016). The generalized discrete $(r|p)$-medianoid problem. *ITOR*, DOI: 10.1111/itor.12289.

Strategic Location Planning under Simulation-based Trip Acceptance for Electric Car-Sharing Systems*

Benjamin Biesinger, Bin Hu, Martin Stubenschrott, Ulrike Ritzinger, and Matthias Prandtstetter

AIT Austrian Institute of Technology
Mobility Department – Dynamic Transportation Systems
Giefinggasse 2, 1210 Vienna, Austria.

⟨firstName⟩.⟨lastName⟩@ait.ac.at

Over the last years the increased air pollution and the awareness for sustainability has lead to a steady growth of the market for privately owned electric vehicles. While so far the high acquisition costs and the limited battery range of these vehicles hinder the wide-spread use, car-sharing systems with electric cars could potentially decrease the use for conventional vehicles in urban areas [5]. Such car-sharing systems offer cars in a pre-defined area which can be rented by customers to perform their desired trips. Compared to systems using conventional cars, in electric car-sharing systems charging stations have to be available within the operational area to recharge the battery of the vehicles. In this work, we consider station-based (in contrast to free-floating) systems in which cars can only be rented and returned at specific stations. The most important strategic decisions when introducing such a system in a new area are where to place the stations, how many charging slots to install, and how many electrical cars to deploy. For being able to make a statement about the viability a demand model is needed which gives a forecast of the customer requests, i.e., when the potential customers want to use a shared car and where they want to go. As the customers are usually willing to walk a short distance to or from a station which is close to their desired starting or ending point, each customer request has a set of potential starting and ending stations. In this work, we model the strategic decisions on the locations of stations, the number of charging slots per station, and the total number of deployed cars with respect to a limited budget as a combinatorial optimization problem and solve it heuristically using a variable neighborhood search. An overview of this and similar optimization problems arising in the area of electric car sharing systems is given by Brandstätter et al. [3, 4].

Simulation-based Trip Acceptance

We approach this problem as a bi-level optimization problem, where we make the strategic decisions on the upper level (using the aforementioned variable

* This work has been partially funded by the Austrian Federal Ministry for Transport, Innovation and Technology (bmvit) in the JPI Urban Europe programme under grant number 847350 (e4share).

neighborhood search) and compute the set of customer requests which can be accepted by the system based on the upper level solution in the lower level problem. As the problem of finding the set of acceptable requests maximizing the profit is itself a difficult optimization problem, we developed several heuristics based on a greedy criterion which are described in [1]. They all use a time discretization and generate a time-expanded location graph in which vehicle paths through space and time are iteratively computed. All state-of-the-art approaches (e.g., [2]) assume, however, a best-case scenario in which the customers behave in such a way that the system's profit is maximized. This means that when there are two requests at the same time at the same station, the more profitable trip would be chosen. In addition, if there are multiple possible stations where a trip can end, the one which is most promising for following trips is selected. As these assumptions are rather unrealistic we focus in this work on a more reasonable computation of the profit. Therefore, we assume that the choice of which trip out of concurrent requests at a station is accepted by the operator and the ending station of the trips are random variables. The profit of the strategic decision on the upper level then depends on the realization of these random variables and we aim to maximize the expected profit. We approximate this expected profit by Monte-Carlo simulations in which each random variable has a uniform probability distribution over its possible realizations.

We tested our approach on real-world data from Vienna, Austria. OpenStreetMap data is used for the underlying road network and we assume potential locations for stations at, e.g., supermarkets. The customer demand model is based on real taxi data. Computational results show that although the expected profit of the simulation-based strategy is lower than using the other strategy and more time-consuming to compute, the price of a more realistic profit estimation is not too high and can pay off in a real-world scenario. For future work we plan to also consider relocation of vehicles which can influence the strategic decisions and is in many practical systems a major factor of the operational costs.

References

1. Biesinger, B., Hu, B., Prandtstetter, M., Ritzinger, U., Stubenschrott, M.: Optimizing charging station locations for electric car sharing systems (2016), submitted to EvoCOP 2017
2. Boyacı, B., Zografos, K.G., Geroliminis, N.: An optimization framework for the development of efficient one-way car-sharing systems. European Journal of Operational Research 240(3), 718–733 (2015)
3. Brandstätter, G., Gambella, C., Leitner, M., Malaguti, E., Masini, F., Puchinger, J., Ruthmair, M., Vigo, D.: Overview of optimization problems in electric car-sharing system design and management. In: Dynamic Perspectives on Managerial Decision Making, pp. 441–471. Springer (2016)
4. Brandstätter, G., Leitner, M., Ljubic, I.: On finding optimal charging station locations in an electric car sharing system. In: Annual workshop of the EURO working group on Vehicle Routing and Logistics optimization (VeRoLog 2016), p. 13 (2016)
5. Pelletier, S., Jabali, O., Laporte, G.: Goods distribution with electric vehicles: Review and research perspectives. Transportation Science 50(1), 3–22 (2016)

Metrics for the evaluation and comparison of graphical model structures

Gabriel Kronberger[1], Bogdan Burlacu[1,2], Michael Kommenda[1,2], Stephan Winkler[1], and Michael Affenzeller[1,2]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, Softwarepark 11, 4232 Hagenberg

[2] Institute for Formal Models and Verification
Johannes Kepler University, Altenbergerstr. 69, 4040 Linz

Background and Motivation[1] Variable interaction networks can be used to describe dependencies between variables of a system [1], [2]. A variable interaction network is a directed graph where each observed variable of the system is represented by a node and dependencies between variables are represented as edges. Variable interaction networks are related to graphical models [3]; building variable interaction networks based on data is therefore closely related to structure learning of graphical models. Variable interaction networks have so far been used primarily for visualization with the aim to gain a better understanding of complex systems (see e.g. [1], [2], [4], [5]). In these applications, statistical models (e.g. symbolic regression models) have been used to identify related variables and to describe empirical dependencies.

Our aim is to use graphical models not only for visualization purposes but also for estimation, simulation, or control in settings where the underlying system has multiple inputs and multiple dependent outputs as well as internal state variables. Ideally, we would like to identify the network of dependencies and derive the structure of the graphical model which can be used for above mentioned purposes. For this we need to solve several problems, one of which is the evaluation of alternative structures for graphical models especially for structure learning. In this contribution we answer the research question: *How can we quantify and compare the correctness of structures of graphical models composed of multiple individual sub-models*?

Methods First, we extend and formalize our definition of the specific type of graphical model starting from the the concept of variable interaction networks. Roughly speaking, the model distinguishes between independent and dependent variables and consists of a set of functions – one for each dependent variable – which are used to estimate dependent variables based on other independent and

[1] The authors gratefully acknowledge financial support by the Austrian Research Promotion Agency (FFG) within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532.

dependent variables. In the full paper we elaborate on the necessary preconditions concerning the underlying system, the observed data, and the modeling algorithm to make structure learning feasible.

Assuming multiple different methods for generating graphical models from data, we want to determine which of those produces the best structure. This can be calculated exactly only if the optimal system structure is known and therefore the learned structures can be compared with the known system structure.

We assume that the modeling methods produce an ordered list of input variables for each dependent variable. For instance variables can be sorted by relevance, explained variance, or the probability that the variable is necessary for explaining the dependent variable. We propose to use one of three indicators to evaluate and compare these variable rankings: (1) Gini coefficient [6], (2) Spearman's rank correlation, and (3) normalized discounted cumulative gain (NDCG) [7]. The Gini coefficient can be used to quantify the discrimination between necessary and unnecessary inputs (binary classification) [6]. Spearman's rank correlation coefficient and NDCG make it possible compare the estimated ranking with the ideal ranking if this is known. The later puts more weight on correctly ordering variables and is better suited.

Results We compared different regression algorithms including linear regression (LR), random forest regression (RF) and symbolic regression (SR). For our set of non-linear synthetic systems with 10, 20, and 50 variables RF is the best method to discriminate between relevant and irrelevant variables and outperforms the other methods especially for the high-dimensional problems. RF also produced the best variable rankings with highest NDCG values. The full results will be given in the full paper.

References

1. Rao, R., Lakshminarayanan, S.: Variable interaction network based variable selection for multivariate calibration. Analytica Chimica Acta **599** (2007) 24 – 35
2. Kronberger, G.: Symbolic Regression for Knowledge Discovery - Bloat, Overfitting, and Variable Interaction Networks. Reihe C: Technik und Naturwissenschaften. Trauner Verlag (2011)
3. Koller, D., Friedman, N.: Probabilistic Graphical Models: Principles and Techniques - Adaptive Computation and Machine Learning. The MIT Press (2009)
4. Kronberger, G., Fink, S., Kommenda, M., Affenzeller, M. In: Macro-economic Time Series Modeling and Interaction Networks. Springer Berlin Heidelberg (2011) 101–110
5. Winker, S., Affenzeller, M., Kronberger, G., Kommenda, M., Wagner, S., Jacak, W., Stekel, H.: Variable interaction networks in medical data. In: Proceedings of the 24th European Modeling and Simulation Symposium EMSS 2012. Dime Università di Genova (2012) 265–270
6. Hand, D.J., Till, R.J.: A simple generalisation of the area under the roc curve for multiple class classification problems. Machine Learning **45** (2001) 171–186
7. Järvelin, K., Kekäläinen, J.: Cumulated gain-based evaluation of ir techniques. ACM Transactions on Information Systems (TOIS) **20** (2002) 422–446

Towards System-Aware Routes*

Matthias Prandtstetter and Clovis Seragiotto

AIT Austrian Institute of Technology
Mobility Department – Dynamic Transportation Systems
`<firstName>.<lastName>@ait.ac.at`
http://www.ait.ac.at/

Keywords: Routing, System-Aware Optimization

1 Introduction

Within this paper, we focus on the development of algorithms capable of providing route suggestions to multiple simultaneously traveling users such that the (negative) impacts of the routes among each other are minimized. We refer to this kind of routes as *system-aware routes*. E.g., if multiple travelers are concurrently following the same route in a street network, it is most likely that traffic congestion occur. If the same set of travelers is, however, distributed over multiple roads/routes, the traffic flow is maintained and negative effects like increased CO_2 emissions are reduced.

Today's routing and navigation devices are, in most cases, not connected with each other, meaning that each user request is handled separately—even if the routing requests are all processed on a centrally operated infrastructure. However, dependent on the availability of traffic data, some devices adapt route suggestions based on observed (or typical) traffic conditions. This behavior leads to a so-called *user equilibrium* (UE) [5] where each traveler cannot reduce her individual travel time choosing another route.

In contrast to an UE, a *system optimum* (SO) [5] consists of a traffic state where the average travel time is minimized. Obviously, this statement is equivalent to the observation that in a SO the overall travel time, i.e. the sum of all travel times, is minimized or the (overall) traffic flow is maximize. Negative environmental impacts caused by traffic congestion are reduced as well. Reaching a SO requires cooperative travelers as well as supporting technologies sharing—among others—(traffic) information with each other.

First solutions to the basic underlying problem of finding a shortest route in a given network reach back to the late 50ies [2]. There were significant improvements in the last decade, especially with respect to speeding-up techniques via pre-processing, cf. [3] or [1] for a more comprehensive survey,. There is, however,

* This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 636160 (OPTIMUM).

only one other work focusing on the system-optimal traffic assignment [4] and—to the best of our knowledge—no other work focusing on the computation of a system optimum with respect to individual routes.

2 Computing System-Aware Routes

The basic problem of finding a route r_i for user $i \in U$, with U denoting the set of users, minimizing the (negative) impacts on all other users $j \in U$, $j \neq i$, can be modeled by:

$$\min \ \alpha \cdot l(r_i) + \beta \cdot \sum_{j \in U \setminus \{i\}} e_i(r_j) \tag{1}$$

$$\text{s.t.} \ \ r_i \text{ is a route from } o(i) \text{ to } d(i), \tag{2}$$

where function l denotes the length of a route, $o(i)$ and $d(i)$ denote the origin and destination of traveler i and function e_i estimates the delay of one route due to another route, i.e. extra travel time due to congestion. Coefficients α and β can be used to (relatively) weight the actual route length to the effects on other routes. It is obvious that this formulation requires an iterative solution procedure if all mutual impacts shall be minimized. Therefore, we suggest a second, alternative formulation leading directly to a SO:

$$\min \ \sum_{i \in U} l(r_i) \tag{3}$$

$$\text{s.t.} \ \ r_i \text{ is a route from } o(i) \text{ to } d(i), \text{for all } i \in U \tag{4}$$

In the presentation, we introduce two algorithmic approaches for solving the two stated problem formulations where for the first an iterated local search is applied and for the second a dynamic program is suggested. Experimental results—including a comparison of the practicability of the approaches—conclude the presentation.

References

1. Delling, D., Goldberg, A., Werneck, R., Pajor, T.: Route planning in transportation networks. Tech. Rep. MSR-TR-2014-4 (January 2014), https://www.microsoft.com/en-us/research/publication/route-planning-in-transportation-networks/
2. Dijkstra, E.W.: A note on two problems in connexion with graphs. Numerische Mathematik 1(1), 269–271 (1959)
3. Geisberger, R., Sanders, P., Schultes, D., Delling, D.: Contraction hierarchies: Faster and simpler hierarchical routing in road networks. In: McGeoch, C.C. (ed.) Experimental Algorithms, Lecture Notes in Computer Science, vol. 5038, pp. 319–333. Springer Berlin Heidelberg (2008)
4. Köhler, E., Möhring, R.H., Skutella, M.: Traffic networks and flows over time. In: Algorithmics of Large and Complex Networks, pp. 166–196. Springer (2009)
5. Wardrop, J.G.: Some theoretical aspects of road traffic research. Proceedings of the Institute of Civil Engineers, Part II 1, 325–378 (1952)

Parallel population-based algorithm for the TSP

Jerzy W. Greblicki PhD.

Department of Control Systems and Mechatronics
Faculty of Electronics
Wrocław University of Science and Technology
Email: Jerzy.Greblicki@pwr.edu.pl

Keywords: Metaheuristic, TSP, parallel algorithms, GPU

Extended abstract

Operational planning in logistic systems is a scientific discipline characterized by dynamic growth. This discipline is inspired by the practical needs, that came from increasing globalization and competition between companies. New technologies, production systems and the organization of work, as well as requirement of reduction of energy consumption and costs relating of environmental degradation, lead to requirement for new comprehensive approach to planning problems.

Effective operational planning requires solving complex (often multi-criteria) very difficult optimization problems, which are characterized by, among other things:

- strong NP-hardness, and thus exponentially increasing computing time of accurate algorithms,
- irregular, not differentiable objective functions and nonlinear constraints,
- the enormous cardinality of solutions set (huge dimension of the solutions space) and just astronomical number of local extremes, the number of decision variables in practice ranges from a few hundred to several thousand,
- chaotic distribution of extremes in space (i.e. the roughness of the fitness landscape).

The aim of this work is to demonstrate that by using theoretical models of properties and using experimental methods, it is possible in practice to identify, analyse and solve complex problems of operational planning in logistics systems. It is also possible to analyse (based on the methods of simulation) multi-criteria goal function for the considered problems. Solution given in this paper shows that solving the problems of operational planning of production systems in logistics are faster than other currently known methods. With a fixed calculations time our method delivers better results, i.e. determined solution is closer to the optimal solution than solution calculated by classical methods.

Metaheuristics based on the method of local search can be presented as problem of searching a graph, in which the vertices are the points of solution space (e.g. permutations), and the edges of graph correspond to neighborhood relations. Edges connect nodes that are neighbors in this space of solutions. Navigating in the graph make a path (trajectory). Multithreaded metaheuristic algorithms use multiple threads, usually running on separate processors or cores, for parallel search in the graph.

There are two approaches to parallelization of local search process, depending on the number of trajectories generated concurrently in the neighbourhood graph:

1. single trajectory: the algorithms fine-grained and medium-grained (as in [3]),
2. multiple trajectory: the algorithms medium-grained and coarse-grained (see [2]).

These approaches put certain requirements for algorithms regarding the frequency of communication between threads. That implies a type of grain. Algorithms grain correspond to the approach of frequent communication: coarse, medium or fine.

Single path algorithms generate a single trajectory. It is possible to create the trajectory by parallel process by dividing a neighborhood on several processors. In each of process we search a part of neighbourhood for the best solution. This idea was proposed earlier for sequential neighbourhood search algorithms by Nowicki and Smutnicki [1] as the method of so-called ‘representatives’. The origin of the name is closely associated with the operation of the algorithm. In each part of neighbourhood representative is elected. Then, among them best solution is chosen as the next representative point of trajectory search. The equivalent parallel method representatives appeared later in the literature [2,3].

Second group of algorithms are multipath algorithms. In the design of multipath algorithms model of concurrent search of solutions space was used. These algorithms can be further divided into subclasses. Subclasses differs because of the exchanged information on the current state of the search: *independent* or *cooperative* search processes.

Independent search processes are defined as concurrently running processes that do not exchange with each other any information during search.. If the information obtained during the exploration of the trajectory of the search process is transferred to another process and then used by the process, we call it cooperative processes

In this paper we will be proposed parallel population based metaheuristic algorithm based on the idea of identifying 'good' parts of solutions (block patterns) and fixing them, and then optimize the remaining elements of the solution. This process will run concurrently not only for the whole population (using a protocol of the MPI), but also locally, in a single solution, using a fine-grained architecture with shared GPU.

References

1. **Nowicki, E., Smutnicki, C**.: *A fast tabu search algorithm for the permutation flow shop problem*. European Journal of Operational Research 19(1), 160–175 (1996)
2. **Bożejko Wojciech, Pempera Jarosław, Smutnicki Czesław:** *Parallel simulated annealing for the job shop scheduling problem*, Lecture Notes in Computer Science, 5544, 631-640, (2009).
3. **Bożejko Wojciech, Smutnicki Czesław, Uchroński Mariusz:** *Parallel calculating of the goal function in metaheuristics using GPU*, Lecture Notes in Computer Science, 5544, 1014-1023, (2009).

GRASP and VNS for a periodic VRP with time windows to deal with milk collection*

Airam Expósito(1), Günther R. Raidl(2), Julio Brito(1), José A. Moreno-Pérez(1)

(1)Department of Computer and Systems Engineering, Universidad de La Laguna, 38271 La Laguna, Canary Islands, Spain.

(2)Institute of Computer Graphics and Algorithms, TU Wien Favoritenstrae 911/1861, 1040, Vienna, Austria.

Keywords: Periodic Vehicle Routing Problem with Time Windows, Quality of Service, Milk Collection, GRASP, VNS, Penalty Functions.

1 Introduction

Logistics and transport management systems for perishable products have operational specificities associated with demands, handling, storage equipment and transport infrastructure. Models to solve the problems of collecting, sharing and distributing these products must adapt to new objectives and constraints. The quality assurance of service and perishable products constitutes the main criterion for the optimization of supply and distribution chains of this kind of goods. In this work we address specifically the problem of planning the collection of fresh milk from local farms through a fleet of refrigerated trucks. The scattered farms of small-scale family type have limited isothermal facilities for storing milk. In these circumstances the collection by the industry demands a precise temporal organization to preserve the quality of the product [4]. The collection planning is done in weekly periods [2]. The problem to determine the most appropriate routes for collecting milk from a set of known farms in a given planning period of several days, including a time window for each pick up, is modelled as Periodic Vehicle Routing Problem with Time Windows (PVRPTW).

2 Periodic Vehicle Routing Problem with Time Windows

The PVRPTW, first mentioned in [3], consists of generation of a limited number of routes for each day over a given planning horizon with the aim to minimize the total travel cost while satisfying the constraints on vehicle capacity, route duration, customer service time windows, and customer visit requirements [5, 6].

With respect to our application in milk collection, we consider a special version of the PVRPTW with an objective function focused on quality of service. The quality of service is improved by reducing the time that farms have to wait to be served within their time windows. This new objective is based on the

* E-mail: aexposito@ull.es, raidl@ac.tuwien.ac.at, jbrito@ull.es, jamoreno@ull.es.

variable s_{ik}, the time when vehicle k arrives at farm i, e_i and l_i are respectively the earliest start time of service and the latest start time of service at the farm i, and n is the number of farms. The objective function is defined as follows:

$$\min \frac{1}{n} \sum \sum \frac{s_{ik} - e_i}{l_i - e_i} \tag{1}$$

The objective function formulation helps milk quality not to be reduced by decreasing the collection milk time during the hours established by the farms.

3 Solution method

Since PVRPTW is an NP-hard problem and VRPs in general are known to be also difficult to solve in practice, metaheuristic methods are appropriated to optimize our model for the milk collection problem and real-world process. We propose a hybrid GRASP-VNS metaheuristics [1] to solve the proposed problem. This hybrid approach uses GRASP as outer framework for diversification and VNS for intensification, i.e., for locally improving and post-processing constructed solutions. The construction phase mechanism of GRASP locates the best position in which to insert a candidate for all routes, minimizing the objective function above, in order to generate the candidate list. Regarding VNS, we use a composition of several neighborhood structures; *2-opt, k-swap chain, k-move chain and change visit combination*. In order to help the hybrid GRASP-VNS finding high quality and feasible solutions, we consider infeasible solutions during the search. Capacity, duration, and time window constraints may be violated and are penalized accordingly. As a specific focus of our work, we experimentally compare different kinds of penalty functions.

References

1. de Armas, J., Lalla, E., Expósito, C., Landa, D., Melián, B.: A hybrid grasp-vns for ship routing and scheduling problem with discretized time windows. Engineering Applications of Artificial Intelligence 45, 350 – 360 (2015)
2. Claassen, G., Hendriks, T.: An application of special ordered sets to a periodic milk collection problem. European Journal of Operational Research 180(2), 754–769 (2007)
3. Cordeau, J.F., Laporte, G., Mercier, A.: A unified tabu search heuristic for vehicle routing problems with time windows. Journal of the Operational Research Society 52(8), 928–936 (2001)
4. Lahrichi, N., Gabriel Crainic, T., Gendreau, M., Rei, W., Rousseau, L.M.: Strategic analysis of the dairy transportation problem. Journal of the Operational Research Society 66(1), 44–56 (2015)
5. Pirkwieser, S., Raidl., G.: A variable neighborhood search for the periodic vehicle routing problem with time windows. In: Proceedings of the 9th EU/MEeting on Metaheuristics for Logistics and Vehicle Routing. pp. 23–24 (2008)
6. Pirkwieser, S., Raidl., G.: Multiple variable neighborhood search enriched with ilp techniques for the periodic vehicle routing problem with time windows. In: HM 2009. LNCS. vol. 5818, pp. 45–59 (2009)

Solving the Traveling Thief Problem using Orchestration in Optimization Networks

Johannes Karder[1,2], Andreas Beham[1,2], Stefan Wagner[1], Michael Affenzeller[1,2]

[1]Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria
Softwarepark 11, 4232 Hagenberg, Austria

[2]Institute for Formal Models and Verification
Johannes Kepler University
Altenbergerstraße 69, 4040 Linz, Austria

{jkarder,abeham,swagner,maffenze}@heuristiclab.com

Extended Abstract

Certain optimization problems are often the construct of multiple subproblems being combined. Solving these subproblems instead of the actual "master problem" can have some advantages. If the subproblems can be reduced to standard problems, it is possible to use already existing solvers, whereas a specialized solver would have to be implemented for the master problem. Also when using multiple solvers, one solver can generate one part of the solution and thus is able to reduce the problem for another cooperative solver.

The NP-hard Traveling Thief Problem (TTP) [1] is one example. The problem definition states that a thief wants to steal items that are stored at different locations. Each item has a certain value and consumes a certain amount of space in the thief's backpack, which has limited storage space. The thief must visit all locations in a round-trip which starts and ends at his hideout. He has to be more careful and thus must move slower the more items he carries and the longer he is buccaneering, the more it costs. The goal is to steal those items in that round-trip so that the overall profit gets maximized. This problem can be divided into a Traveling Salesman Problem (TSP) and a Knapsack Problem (KSP). The TSP optimizer is used to generate profitable tours, whereas the KSP optimizer is used to yield good item selections. Both problems are then solved in collaboration [2].

To manage a collaborative optimization approach, the concept of "orchestrators" is used, which can be seen in Figure 1. Orchestrators are entities that are able to steer subproblem optimizers in two different ways:

- They can recalculate actual solution qualities of subproblems.
- They can adapt the problem parameters to yield better solution qualities for the original problem instances.

The authors gratefully acknowledge financial support by the Austrian Research Promotion Agency (FFG) within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532.

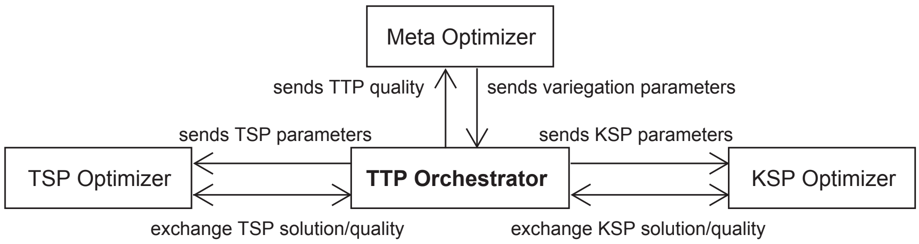


Fig. 1. The orchestrator steers the TSP and KSP optimizers. A meta optimizer is used to optimize problem variegation parameters, e.g. KSP weights or TSP coordinates.

By changing a subproblem's fitness landscape, the respective optimizer converges to other areas of the search space that it would have ignored in the original problem instance, because solutions in this area would be evaluated as weak right away. Depending on the chosen orchestration strategy, the orchestrator will interact with the optimizers on a quality adaptation or problem variegation basis, for which it is necessary to define according routines. These routines are problem-specific, therefore specialized orchestrators have to be provided for each problem that will be divided into subproblems. We implement a specialized orchestrator for the TTP to be used within the HeuristicLab optimization environment [3].

Connecting different subproblem optimizers to orchestrators can be done using so called optimization networks. Such networks are composed of multiple nodes that are able to communicate with each other. The goal is to design a network node (i.e. "orchestrator node") as a generic approach to orchestration in such optimization networks. At first, a well-conceived architecture is created, which makes it possible to implement problem-specific orchestrator nodes with little effort. A specific TTP orchestrator is then used to steer the overall optimization approach. We will experiment with both techniques and different orchestration routines. In the end we compare the achieved results and conclude with possible future work on this matter.

References

1. Bonyadi, M.R., Michalewicz, Z., Barone, L.: The travelling thief problem: the first step in the transition from theoretical problems to realistic problems. In: 2013 IEEE Congress on Evolutionary Computation, IEEE (2013) 1037–1044
2. Beham, A., Fechter, J., Kommenda, M., Wagner, S., Winkler, S.M., Affenzeller, M.: Optimization strategies for integrated knapsack and traveling salesman problems. In: International Conference on Computer Aided Systems Theory, Springer (2015) 359–366
3. Wagner, S., Kronberger, G., Beham, A., Kommenda, M., Scheibenpflug, A., Pitzer, E., Vonolfen, S., Kofler, M., Winkler, S., Dorfer, V., Affenzeller, M.: Architecture and Design of the HeuristicLab Optimization Environment. In: Advanced Methods and Applications in Computational Intelligence. Volume 6 of Topics in Intelligent Engineering and Informatics. Springer (2014) 197–261

Optimizing the Movement of Containers on the Yard of a Maritime Container Terminal

Israel López-Plata, Christopher Expósito-Izquierdo, Belén Melián-Batista, and J. Marcos Moreno-Vega*

Department of Computer Engineering and Systems
Universidad de La Laguna
38271 La Laguna, Spain
{ilopezpl, cexposit, mbmelian, jmmoreno}@ull.es

1 Introduction

Maritime container terminals are complex infrastructures to manage in transport industry due to their high degree of uncertainty arisen from the limited and changing information. The containers in a maritime container terminal are moved around the terminal by means of internal delivery vehicles, known as automated guided vehicles, in short AGVs.

The main objective of this work is to optimize the usage of the available AGVs in a maritime container terminal in terms of working time. This optimization is contextualized in scenarios that change dynamically and in which synchronization is required.

2 Internal Delivery Vehicle Synchronization Problem

The Internal Delivery Vehicle Synchronization Problem, IDVSP, pursues to manage the available fleet of AGVs efficiently in a maritime container terminal. Let J be the set composed of jobs, which have to be performed by a fleet of internal delivery vehicles, denoted as V. A job refers to the movement of a certain container from some source position towards another target position, both positions are known in advance. Performing a job involves moving an AGV towards its source position, picking up the relevant container, moving towards its target position, and lastly delivering the container.

The feasible solutions of the IDVSP are composed of routes to be followed by the internal delivery vehicles in V and with the aim of performing the existing jobs, J. The route of a given internal delivery vehicle departs from a known initial position on the yard and visits consecutively the source and target positions of the subset of jobs assigned to it on a specific order. It is worth mentioning that

* This work has been partially funded by the Spanish Ministry of Economy and Competitiveness with FEDER funds (projects TIN2012-32608 and TIN2015-70226-R). Christopher Expósito-Izquierdo would like to thank the Canary Government for the financial support he receives through his post-graduate grant

all the jobs included in J must be performed by an internal delivery vehicle. In this environment, the objective of the IDVSP is to minimize the time required by the vehicles when performing the jobs. That is, minimizing the makespan of the underlying schedule.

In contrast to the classic Vehicle Routing Problem (VRP) [2], the IDVSP takes into account synchronization when picking up and dropping off containers. In those cases in which several AGVs try to access simultaneously to a given position, they are queued in such a way that only one of them can perform its assigned job. In those scenarios in which synchronization is not required, the IDVSP addressed in this work can be easily reduced to the VRP with pick-ups and deliveries [1]. Thus, it can be claimed that it is also $\mathcal{NP}$-hard.

3 Optimization Approach

In order to solve the IDVSP, an efficient algorithmic technique based upon the framework of the well-known Variable Neighbourhood Search [3], in short VNS, is here proposed. The first step of the algorithm is to build at each iteration an initial solution by means of a constructive method. This assigns a similar number of jobs to each vehicle randomly. Departing from this solution, the proposed algorithm performs an exploration of its different neighbourhoods, with the goal of finding the best of its local optima.

Before exploring each neighbourhood, the solution applies a shaking process, which generates a random neighbour of the solution using the current neighbourhood. This allows to start the local search to find the local optima from different solutions at each iteration. Whenever the local optimum obtained improves the best solution, the exploration of the neighbourhoods starts again. In other case, the algorithm continues with the exploration of the next neighbourhood until all available neighbourhoods have been examined. The neighbourhood structures used in this work are *Interchange*, *Reinsertion*, and *Two-opt*.

In order to assess the suitability of our VNS, we have analysed its performance in comparison with three algorithmic techniques: a local search, a random search and a multi-start search with multiple environments. The experiments are done in a wide range of realistic scenarios. The computational results indicate that our approach returns high-quality solutions in all the scenarios by means of short computational times.

References

1. G. Berbeglia, J.F. Cordeau, I. Gribkovskaia, and G. Laporte. Static pickup and delivery problems: a classification scheme and survey. *TOP*, 15(1):1–31, 2007.
2. G. B. Dantzig and J. H. Ramser. The truck dispatching problem. *Management Science*, 6(1):80–91, 1959.
3. P. Hansen, N. Mladenović, J. Brimberg, and J.A. Moreno-Pérez. Variable neighborhood search. In M. Gendreau and J.Y. Potvin, editors, *Handbook of Metaheuristics*, volume 146 of *International Series in Operations Research & Management Science*, pages 61–86. Springer US, 2010.

A Meta-heuristic Approach for the Transshipment of Containers in Maritime Container Terminals

Kevin Robayna-Hernández, Christopher Expósito-Izquierdo, Belén Melián-Batista, and J. Marcos Moreno-Vega*

Department of Computer Engineering and Systems
Universidad de La Laguna
38271, La Laguna, Spain
{krobayna, cexposit, mbmelian, jmmoreno}@ull.es

1 Introduction

Maritime terminals are highlighted infrastructures which are nowadays handling about 10 billion tons of goods worldwide, according to the United Nations Conference on Trade And Development[1]. They are aimed at enabling the transshipment of freights between different transportation means. However, their main objective is to serve the incoming container vessels, which arrive to the terminal with the goal of loading and unloading containers efficiently.

This work presents a Variable Neighbourhood Search for the optimization of the transshipment of containers at maritime container terminals. Its objectives are to minimize (i) the departure times of the container vessels arrived to the port and (ii) the costs derived from moving containers around the terminal.

2 Transshipment of Containers

The transshipment operations at maritime terminals refer to the movement of containers carried out between the sea-side and the yard of the infrastructure [2]. This way, every time a vessel arrives to port, a subset of its containers are unloaded from it and later stored on the yard. Similarly, a set of containers is loaded into the vessel to be transported to the next port along its shipping route.

In this work, we pursue to solve a variant of the Berth Allocation Problem [4] in which the objective is to determine a berth for each incoming vessel that satisfies its particular requirements (*i.e.*, dimensions, time window, service constraints, etc.). In this environment, the container vessels arrived to the terminal has to be assigned to a berth while their services have to be carried out within

* This work has been partially funded by the Spanish Ministry of Economy and Competitiveness (projects TIN2012-32608 and TIN2015-70226-R) and with FEDER funds. Christopher Expósito-Izquierdo would like to thank the Canary Government for the financial support he receives through his post-graduate grant

[1] http://www.unctad.org

their time windows. Additionally, only one vessel can be served in a berth at once. Lastly, it is required to determine an appropriate position on the yard for the containers to unload. It is worth mentioning that the position of each container to (un)load has a great impact on the service of the vessel due to the growth of the times required to move the containers aroud the terminal [1].

3 Variable Neighbourhood Search

This work proposes an efficient meta-heuristic approach based upon the well-known framework of the Variable Neighbourhood Search [3] (VNS) with the aim of solving the optimization problem introduced previously.

The proposed meta-heuristic approach generates solutions by means of a greedy procedure. This is aimed at assigning a berth for each incoming vessel according to its particular characteristics and the availability of the functional areas of the terminal. Simultaneously, this procedure schedules the vessels into each berth in such a way that their time windows are satisfied. Once the initial solution is obtained, this is improved by means of an adaptive exploration scheme of its neighbourhood, which is defined on the basis of three neighbourhood structures: (i) re-insertion of vessels, (ii) swap of vessels, and (iii) interchange of container destinations on the yard. In addition, an effective shaking scheme is proposed to diversify the search and reach promising regions of the solution space.

The optimization approach proposed in this work has been coded in Java SE 8. It has been tuned and tested on a computer equipped with an Intel 3.16 GHz and 4 GB of RAM. The test problem instances have been generated according to realistic features of large maritime container terminals. In this regard, the computational experiments indicate that our approach is able to report high-quality solutions in short computational times. The results show that the approach is able converge to (near-)optimal solutions in a reduced number of iterations while keeping a high level of diversification. Finally, the results are robust when the varying the characteristics of the problem instances to solve, which indicates that the approach is suitable for being applied in realistic environments.

References

1. E.K. Bish, F.Y. Chen, Y.T. Leong, B.L. Nelson, J.W.C. Ng, and D. Simchi-Levi. Dispatching vehicles in a mega container terminal. *OR Spectrum*, 27(4):491–506, 2005.
2. J.W. Böse. General considerations on container terminal planning. In J.W. Böse, R. Sharda, and S. Voβ, editors, *Handbook of Terminal Planning*, volume 49 of *Operations Research/Computer Science Interfaces Series*, pages 3–22. Springer, 2011.
3. P. Hansen, N. Mladenović, J. Brimberg, and J.A. Moreno-Pérez. Variable neighborhood search. In M. Gendreau and J.Y. Potvin, editors, *Handbook of Metaheuristics*, volume 146 of *International Series in Operations Research & Management Science*, pages 61–86. Springer US, 2010.
4. F. Meisel. *Seaside operations planning in container terminals.* Springer, 2009.

Multi-Objective Topology Optimization of Electrical Machine Designs using Evolutionary Algorithms with Discrete and Real Encodings

Alexandru-Ciprian Zăvoianu[1], Gerd Bramerdorfer[2,3], Edwin Lughofer[1], Susanne Saminger-Platz[1]

[1] Department of Knowledge-based Mathematical Systems/Fuzzy Logic Laboratory Linz-Hagenberg, Johannes Kepler University of Linz, Austria
[2] Institute for Electrical Drives and Power Electronics, Johannes Kepler University of Linz, Austria
[3] LCM, Linz Center of Mechatronics, Linz, Austria

Workshop: Theory and Applications of Metaheuristic Algorithms
Keywords: evolutionary algorithms, multi-objective optimization, discrete encoding, real encoding, topology optimization, electrical drive designs

Extended abstract

Classically, designing electrical drives that are (simultaneously) optimal with regard to given criteria – e.g., energy efficiency, costs, fault tolerance, etc. – is a two step procedure. In the first step, a domain expert defines the complete geometric specifications of future designs. This means that the human expert actually creates / chooses a parametric model that will act as a generic template for any subsequent electrical drive that aims to solve the given task. In the second step, a (usually multi-objective) optimization method is employed to find those sets of parameter combinations that, when applied on the chosen generic template, produce (Pareto-)optimal design instances.

Even when carrying out the optimization part via state-of-the-art solvers, like hybrid multi-objective evolutionary algorithms (MOEAs) [6] and particle swarm optimization [1], one can easily argue that the truly creative part of the design process remains with the domain expert. When the wrong parametric model for the task at hand is chosen, no amount of optimization will be able to deliver good results. Thus, by imposing hard constraints in variable space, a choice for a parametric model actually entails restrictions on the shape of possible designs.

Direct *topology optimization* [3] is an alternative approach that, when applicable, seems better suited to fully benefit from the explorative strength of modern MOEAs and recent advances in simulation software and computation power [4]. In this case, the domain expert only needs to define the boundaries of the design region and to choose a discretization factor. This results in a grid in which each cell can be parameterized from a limited set of values. The simplest of such sets contains only two elements: iron and air. The task of the MOEA is to find those grid configurations (i.e., discrete matrices) that encode Pareto-optimal solutions. All in all, since the optimization problem is formulated in a far less restrictive manner, the optimization algorithm also "becomes responsible" for the more advanced / creative part of the design automation process.

In order to gain insight regarding the performance of MOEAs on direct topology optimization problems, we performed several experiments. Firstly, we applied classical MOEAs like NSGA-II [2] and SPEA2 [5] with basic genetic operators suitable for a discrete encoding: binary crossover and bit flip mutation. Interestingly, very good Pareto fronts and convergence behaviors were obtained in a second series of tests when adopting a rather counter-intuitive real encoding of the topology matrices that facilitates the use of more advanced optimization methods that also integrate differential evolution operators and decomposition-based search space exploration strategies.

Acknowledgments

This work was supported by the K-Project "Advanced Engineering Design Automation" (AEDA) that is financed under the COMET (COMpetence centers for Excellent Technologies) funding scheme of the Austrian Research Promotion Agency.

This work was partially conducted within LCM GmbH as a part of the COMET K2 program of the Austrian government. The COMET K2 projects at LCM are kindly supported by the Austrian and Upper Austrian governments and the participating scientific partners. The authors thank all involved partners for their support.

References

1. Bittner, F., Hahn, I.: Kriging-assisted multi-objective particle swarm optimization of permanent magnet synchronous machine for hybrid and electric cars. In: IEEE International Electric Machines & Drives Conference (IEMDC 2013). pp. 15–22. IEEE (2013)
2. Deb, K., Pratap, A., Agarwal, S., Meyarivan, T.: A fast and elitist multiobjective genetic algorithm: NSGA-II. IEEE Transactions on Evolutionary Computation 6(2), 182–197 (2002)
3. Im, C.H., Jung, H.K., Kim, Y.J.: Hybrid genetic algorithm for electromagnetic topology optimization. IEEE Transactions on Magnetics 39(5), 2163–2169 (2003)
4. Silber, S., Koppelstätter, W., Weidenholzer, G., Bramerdorfer, G.: Magopt-optimization tool for mechatronic components. In: Proceedings of the ISMB14-14th International Symposium on Magnetic Bearings (2014)
5. Zitzler, E., Laumanns, M., Thiele, L.: SPEA2: Improving the strength Pareto evolutionary algorithm for multiobjective optimization. In: Evolutionary Methods for Design, Optimisation and Control with Application to Industrial Problems (EUROGEN 2001). pp. 95–100. International Center for Numerical Methods in Engineering (CIMNE) (2002)
6. Zăvoianu, A.C., Bramerdorfer, G., Lughofer, E., Silber, S., Amrhein, W., Klement, E.P.: Hybridization of multi-objective evolutionary algorithms and artificial neural networks for optimizing the performance of electrical drives. Engineering Applications of Artificial Intelligence 26(8), 1781–1794 (2013)

Meta-learning-based System for solving Logistic Optimization Problems

Alan Davila de León, Eduardo Lalla-Ruiz, Belén Melián-Batista, and J. Marcos Moreno-Vega

Department of Computer Engineering and Systems
University of La Laguna. La Laguna, Spain
{alan.davila,mbmelian,jmmoreno}@ull.es

Institute of Information Systems
University of Hamburg. Hamburg, Germany
eduardo.lalla-ruiz@uni-hamburg.de

1 Introduction

The Algorithm Selection Problem (ASP) is introduced in [5] seeking to answer the question *"Which algorithm is the best option to solve my problem?"* under those cases where the decision-maker or solver counts with more than one algorithm for a given problem. Formally, the ASP can be defined as follows: having a problem instance $x \in P$, with given features $f(x) \in F$, the objective is to perform a selection mapping $S(f(x))$ in the algorithms space A, with the goal of selecting the algorithm $\alpha \in A$ that maximizes the performance mapping $y(\alpha, x) \in Y$ such that $y(\alpha, x) \geq y(a, x)\,, \forall a \in A$. Thus, the principal components of the algorithm selection model are: the problem space P, the feature space F, the selection mapping S of P on the algorithm space A and the performance space Y. The importance of tackling this problem is provided by: (*i*) No Free Lunch (NFL) theorem, (*ii*) the big number of available algorithms, and (*iii*) the need of trying to obtain the best possible solution, and not only a correct one.

In the related literature, some systems have been proposed. The Machine Learning Toolbox (MLT) project [2], continued in Statlog [3] and METAL [1], aims to select the best algorithm for a given dataset. Furthermore, in [1] a helping system for aiding the selection of machine learning algorithms, according to the dataset is proposed. They obtain meta-features that allow to compare different datasets and, by means of that, obtain a reduced group of datasets similar to the one at hand. Those reduced groups are later used to give a recommendation. In [7] a multilayer perceptron network (MLP) is used to select the best optimization algorithm to solve the quadratic assignment problem. However, the above mentioned contributions and systems are focused on recommending or choosing algorithms for a particular problem. That is why a meta-learning ([4]) based system may be appropriate and necessary for those scenarios where a ranking of algorithms sorted according to a provided criterion for any supported input problem is necessary. On the other hand, a drawback appearing in algorithm selection systems is the so-called cold start (see [6]). It concerns the disadvantage that arises in those cases where the system involved in the selection of the algorithm for providing a solution has not enough information to give an appropriate recommendation or selection. An extreme case of this problem happens when the system has not past information for comparing the input stream.

2 Contribution

Bearing the previous discussion in mind, the main goal of this work is two-fold. On the one hand, a novel meta-learning-based approach that allows to select, from a pool of algorithms, a suitable algorithm for solving a given logistic problem (e.g., vehicle routing problem, berth allocation problem, facility location, etc.) is proposed. On the other hand, the proposed approach is enabled to work within cold start situations where although the system do not have previous information of an introduced logistic problem, it may count with information from a similar problem or from a generalization of it. In doing so, a tree structured hierarchy that allows to compare different metric dataset to identify a particular problem or variation is presented.

References

1. Brazdil, P.B., Soares, C., Da Costa, J.P.: Ranking learning algorithms: Using ibl and meta-learning on accuracy and time results. Machine Learning 50(3), 251–277 (2003)
2. Kodratoff, Y., Sleeman, D., Uszynski, M., Causse, K., Craw, S.: Building a machine learning toolbox. Enhancing the Knowledge Engineering Process pp. 81–108 (1992)
3. Michie, D., Spiegelhalter, D.J., Taylor, C.C.: Machine learning, neural and statistical classification (1994)
4. Pappa, G.L., Ochoa, G., Hyde, M.R., Freitas, A.A., Woodward, J., Swan, J.: Contrasting meta-learning and hyper-heuristic research: the role of evolutionary algorithms. Genetic Programming and Evolvable Machines 15(1), 3–35 (2014)
5. Rice, J.R.: The algorithm selection problem. Advances in computers 15, 65–118 (1976)
6. Schein, A.I., Popescul, A., Ungar, L.H., Pennock, D.M.: Methods and metrics for cold-start recommendations. In: Proceedings of the 25th annual international ACM SIGIR conference on Research and development in information retrieval. pp. 253–260. ACM (2002)
7. Smith-Miles, K.: Towards insightful algorithm selection for optimisation using meta-learning concepts. In: WCCI 2008: IEEE World Congress on Computational Intelligence. pp. 4118–4124. IEEE (2008)

Analysing a Hybrid Model-Based Evolutionary Algorithm for a Hard Grouping Problem

Sebastian Raggl[1], Andreas Beham[1,2], and Michael Affenzeller[1,2]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, 4232 Hagenberg
[2] Institute for Formal Models and Verification
Johannes Kepler University, 4040 Linz, Austria
sebastian.raggl@fh-hagenberg.at

1 Motivation and Method

We present a new NP hard grouping problem derived from a real world problem where transports lots have to be formed from various items. This problem is challenging even for state of the art optimization algorithms, as we show by attacking real world test instances using a variety of algorithms.

Both memetic algorithms (MA)[1] as well as estimation of distribution algorithms (EDA)[2] have attracted a significant amount of research interest in recent years. To solve this problem efficiently we propose using a hybrid algorithm that aims to combine these two approaches with an evolutionary algorithm. The algorithm presented in this paper uses five main operations:

- Creation heuristic
- Selection, Crossover and Mutation
- Sampling from a bivariate model
- Path-relinking procedure
- Local improvement procedure

The encoding used is the Linear-Linkage-Encoding [3] with the crossover and mutation operators described in [4].

In order to find a good hybridization we need to understand the role of and the interplay between the different heuristics. To that end we analyse the influence of the different operators on the results as well as on the characteristics of optimization runs, by testing different combinations and looking at the fitness and diversity of the population over time.

2 Problem

Given is a set of items that need to be assigned to an ordered set of groups. We want to find the assignment to the smallest number of groups with the lowest total cost.

$\mathcal{I} = \{i\}_{i=1}^{N}$	Set of items
$\mathcal{S} = \{s\}_{s=1}^{S}$	Ordered set of transport lots
$G_p = (\mathcal{I}, R)$	Weighted undirected graph of pairwise grouping costs
$G_d = (\mathcal{I}, \mathcal{D})$	Directed graph of item dependencies

$$\min \ |S| + \sum_{s \in \mathcal{S}} C(s) \tag{1}$$

$$s.t. \ (a,b) \in R \qquad \forall_{s \in \mathcal{S}} \ \forall_{a \in s,\ b \in s} \tag{2}$$

$$S(a) \leq S(b) \qquad \forall_{(a,b) \in \mathcal{D}} \tag{3}$$

The function $C(\mathcal{S}) \rightarrow \mathbb{R}$ calculates the costs of a group lot using the weights on G_p. If a edge in G_p has a high weight placing the two items connected by that edge in the same group is unfavourable. Two items that do not share an edge in G_p must not be in the same group which is ensured by constraint 2. Constraint 3 guarantees that every item that depends on another one is either in the same group or in a group with a bigger index than the item it depends on. The function $S(\mathcal{I}) \rightarrow \mathbb{Z}$ maps an item to the index of the group it belongs to.

Acknowledgements

The work described in this paper was done within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532 funded by the Austrian Research Promotion Agency (FFG).

References

1. Amaya, J.E., Cotta Porras, C., Fernández Leiva, A.J.: Memetic and hybrid evolutionary algorithms. In: Springer Handbook of Computational Intelligence. Springer Berlin Heidelberg (2015) 1047–1060
2. Pelikan, M., Hauschild, M.W., Lobo, F.G.: Estimation of distribution algorithms. In: Springer Handbook of Computational Intelligence. Springer Berlin Heidelberg (2015) 899–928
3. Du, J., Korkmaz, E., Alhajj, R., Barker, K.: Novel clustering approach that employs genetic algorithm with new representation scheme and multiple objectives. In: Data Warehousing and Knowledge Discovery: 6th International Conference, DaWaK 2004, Zaragoza, Spain, Springer Berlin Heidelberg (2004) 219–228
4. Ülker, Ö., Özcan, E., Korkmaz, E.E.: Linear linkage encoding in grouping problems: Applications on graph coloring and timetabling. In: Practice and Theory of Automated Timetabling VI: 6th International Conference, PATAT 2006 Brno, Czech Republic, Springer Berlin Heidelberg (2007) 347–363

Solving a Weighted Set Covering Problem for Improving Algorithms for Cutting Stock Problems with Setup Costs by Solution Merging

Benedikt Klocker, Günther R. Raidl

Institute of Computer Graphics and Algorithms, TU Wien, Vienna, Austria
{klocker|raidl}@ac.tuwien.ac.at

1 Introduction

There are many different kinds of cutting stock problems (CSPs) occurring in practice and in theory having in common that they ask for a set of patterns, where each pattern is a collection of elements, to satisfy given element demands while minimizing the costs of the patterns. The classical CSP only considers fixed costs for each individual pattern, but in many practical applications an additional cost factor are setup costs arising whenever the machine has to be set up to cut a different pattern. Thus, finding a solution involving a small number of different types of patterns is often preferred.

Most approaches to solve CSPs generate many candidate solutions yielding, if collected, a large and diverse set of patterns. We formalize an extension of the weighted set covering problem which exploits all these collected patterns by deriving an optimal combination of a subset of them resembling a feasible, possibly new incumbent solution. Solving this subproblem can be seen as a kind of solution merging. It can be applied either as a post-processing or as an intermediate step to also lead the pattern construction in a more promising direction. We investigate this extension specifically on K-staged two-dimensional CSPs with setup costs.

The merging problem is defined as follows. Given is a set of elements $E = \{1, \ldots, n\}$ with a demand vector $(d_i)_{i=1}^n \in \mathbb{N}^n$ and the set of collected patterns P. The actual structure of the patterns is not relevant here, but each pattern $p \in P$ has an associated element vector $(e_i^p)_{i=1}^n \in \mathbb{N}^n$ indicating how often an element $i \in E$ occurs in p. Every pattern $p \in P$ has associated production costs c_p^{P} and setup costs c_p^{S}. The goal is to find amounts $a = (a_p)_{p \in P} \in \mathbb{N}^{|P|}$ such that

$$c(a) := \sum_{p \in P} c_p^{\mathrm{P}} \cdot a_p + \sum_{p \in P \,:\, a_p > 0} c_p^{\mathrm{S}}$$

is a minimum and the demands are satisfied, i.e. $\sum_{p \in P} e_i^p \cdot a_p \geq d_i,\ i = 1, \ldots, n$.

2 Related Work

In [1] a similar approach is considered for the one dimensional CSP, where each pattern has the same production and setup costs. An integer linear programming

(ILP) model is proposed and solved by CPLEX. In an older work Foerster and Wascher [2] present a two phase approach with a pattern reduction in the second phase. A more theoretical analysis of a general weighted set covering problem is done in [3], where no concept like setup costs were considered. We use the methods described in [4] as base algorithm yielding the collection of patterns.

3 Solution Approaches

Similarly as in [1], we can solve our problem directly with an ILP solver. Since this exact approach does not scale very well we also consider a greedy heuristic.

This greedy approach starts with no selected patterns and selects promising patterns until all demands are satisfied. To decide in a greedy manner which pattern we choose next we keep track of the unsatisfied demands $(u_i)_{i=1}^n$ which get initialized with $u_i = d_i$. To rate the quality of a pattern we use a size value $v_i \in \mathbb{R}$ for each element $i \in E$. In the one-dimensional case this is the length, in the two-dimensional case the area of the element. In each step, we select a best pattern p together with an amount a according to the following rating

$$r(p,a) := \frac{\sum_{i=1}^n \max\left(a \cdot e_i^p, u_i\right) \cdot v_i}{a \cdot c_p^{\mathrm{P}} + c_p^{\mathrm{S}} \cdot \delta_p}$$

where $\delta_p = 1$ if pattern p is not already in the solution and $\delta_p = 0$ if p was already added in a previous step. We add a pattern p with a maximal rating $r(p,a)$ with amount a to our current solution and recalculate the u_i values. We stop when $u_i = 0$ for all i.

We compare the greedy algorithm with the exact ILP approach on real-world instances. Results indicate that the greedy approach is substantially faster, scales much better, and nevertheless yields solutions of almost equal quality.

The greedy approach is further extended with the preferred iterative lookahead technique (PILOT) resulting in better solution qualities for some instances, however, at the cost of longer running times. Furthermore some considered extensions are disallowing overproduction of elements, i.e. satisfying demands exactly, limiting the number of patterns for one setup, and limiting the amount of different sheet types.

References

1. Cui, Y., Zhong, C., Yao, Y.: Pattern-set generation algorithm for the one-dimensional cutting stock problem with setup cost. European Journal of Operational Research **243**(2) (2015) 540–546
2. Foerster, H., Wascher, G.: Pattern reduction in one-dimensional cutting stock problems. International Journal of Production Research **38**(7) (2000) 1657–1676
3. Yang, J., Leung, J.Y.T.: A generalization of the weighted set covering problem. Naval Research Logistics **52**(2) (2005) 142–149
4. Dusberger, F., Raidl, G.R. In: A Scalable Approach for the K-Staged Two-Dimensional Cutting Stock Problem with Variable Sheet Size. Volume 9520 of LNCS. Springer (2015) 384–392

Particle Therapy Patient Scheduling: Time Estimation to Schedule Sets of Treatments*

Johannes Maschler, Martin Riedler, and Günther R. Raidl

Institute of Computer Graphics and Algorithms, TU Wien, Vienna, Austria
{maschler|riedler|raidl}@ac.tuwien.ac.at

1 Introduction

In classical radiotherapy cancer treatments are provided by linear accelerators that serve a dedicated treatment room exclusively. In contrast, particle therapy uses beams that are produced by either cyclotrons or synchrotrons that can serve up to five treatment rooms in an interleaved way. Several sequential activities like stabilization not requiring the beam have to be performed in the treatment room before and after each actual irradiation. Using several rooms and switching the beam between the rooms thus allows an effective utilization of the expensive particle accelerator and increased throughput of the facility.

In a typical midterm planning scenario a schedule for performing the therapies over the next few months has to be determined. Midterm planning for classical radiotherapy has already attracted some research starting with the works from Kapamara et al. [1] and Petrovic et al. [3]. Due to the one-to-one correspondence of treatment rooms and accelerators it suffices to consider a coarser scheduling scenario in which treatments have to be assigned only to days but do not have to be sequenced within the day. In a recent work [2] we studied a simplified problem formulation addressing the midterm planning of the particle therapy treatment center MedAustron in Wiener Neustadt, Austria, which offers three treatment rooms. Our approach consisted in decomposing the problem into a day assignment and a sequencing part, and we provided a construction heuristic, a GRASP, and an Iterated Greedy (IG) metaheuristic. The aim of the current work is to extend the proposed model and to provide and utilize a mechanism that quickly predicts the behavior of the sequencing part with reasonable precision, allowing in particular an improved day assignment.

2 Particle Therapy Patient Scheduling Problem

In the Particle Therapy Patient Scheduling Problem (PTPSP) therapies consisting of daily treatments (DTs) on 8 to 35 subsequent days have to be planned. Each therapy has a window of days at which it is allowed to start. There is a minimal and maximal number of DTs that have to be provided each week, a lower and upper bound of days that are allowed to pass between two subsequent

* We thank EBG MedAustron GmbH, Wiener Neustadt, Austria, for the collaboration on particle therapy patient scheduling and partially funding this work.

DTs, and a required break of at least two consecutive days each week. Moreover, DTs should be provided roughly at the same time within each week. Each DT consists of either five or seven consecutive activities having associated processing times and requiring individual resources such as the particle beam, room, and anesthetist. Resources have each day a regular and an extended availability period at which they can be used, where the use of the latter one results in additional costs. The availability periods of resources can be further interrupted by so-called unavailability periods.

A schedule assigns all DTs of a given set of therapies to days and determines starting times for the associated activities considering all operational constraints. The considered objective minimizes the use of extended availability periods, the finishing day of the therapies, and the variation of the starting times of the DTs.

3 Solution Approach and Time Estimation

Our solution approach consists of decomposing PTPSP into the Day Assignment (DA) in which DTs are assigned to days and the Time Assignment (TA) in which for each day starting times for the respective DTs activities are determined. Clearly, those two levels are dependent on a large degree. Determining the usage of the resources' availability periods for a given candidate set of DTs at a specific day is of crucial interest in any method determining an optimized DA as well as any constructive heuristic for the TA. Optimally solving the associated subproblem, however, would in general require to completely solve the underlying scheduling problem, which is very time-expensive if practically possible at all. Therefore, we investigate different efficient ways to estimate the use of the resources' availability periods with reasonable accuracy and study the impact on the greedy heuristic, GRASP, and IG.

Furthermore, in [2] we did not yet regard the requirement that each therapy's DTs should be provided at roughly the same time. This allowed a more independent calculation of the TA for each day. We now extend our methods to also address this soft-constraint. The main idea is that in the underlying construction heuristic the days are now considered sequentially and DTs are assigned preferably to starting times that are close to starting times of previous DTs.

References

1. Kapamara, T., Sheibani, K., Haas, O., Petrovic, D., Reeves, C.: A review of scheduling problems in radiotherapy. In: Proceedings of the International Control Systems Engineering Conference (ICSE). pp. 207–211. Coventry University Publishing, Coventry, UK (2006)
2. Maschler, J., Riedler, M., Stock, M., Raidl, G.R.: Particle therapy patient scheduling: First heuristic approaches. In: Proceedings of the 11th Int. Conference on the Practice and Theory of Automated Timetabling. Udine, Italy (2016)
3. Petrovic, S., Leung, W., Song, X., Sundar, S.: Algorithms for radiotherapy treatment booking. In: 25th Workshop of the UK Planning and Scheduling Special Interest Group. pp. 105–112. Nottingham, UK (2006)

Heuristic Approaches to Scheduling Recurring Radiotherapy Treatment Activities with Alternative Resources, Optional Activities and Time Window Constraints

EUROCAST 2017 – Workshop on Theory and Applications of Metaheuristic Algorithms

Petra Vogl*, Roland Braune, and Karl F. Doerner

Department of Business Administration
Faculty of Business, Economics and Statistics, University of Vienna
Oskar-Morgenstern-Platz 1, 1090 Vienna, Austria
{petra.vogl,roland.braune,karl.doerner}@univie.ac.at
https://plis.univie.ac.at/

The Radiotherapy Patient Scheduling Problem (RPSP) is concerned with the assignment of irradiation treatment appointments to patients diagnosed with cancer. A radiation therapy consists of a pre-treatment phase and the treatment phase itself, which in turn consists of multiple daily treatments (DT) requiring numerous resources as well as staff capacity simultaneously. Some of those daily treatments are followed by optional imaging activities or doctoral assignments. Optimizing the associated irradiation appointments is crucial in order to treat as many patients as possible during the restricted availability times of the resources, where usually each resource has a maximum capacity of one patient at a time.

The outlined problem can in general be classified as a Job Shop Scheduling Problem. However, various of its characteristics require advanced scheduling techniques: First, we consider multiple alternative (and preferred) resources with multiple non-availability periods during the planning horizon. Second, we incorporate optional activities into the model. These activities need to take place, e.g. once a week, with the exact day of execution to be optimized. Third, all treatment activities of a patient are tied together using minimum and maximum time lags, whose violation results in a penalty within the objective function. Further, the starting times of the recurring irradiation treatments should remain relatively stable over all treatment days aiming at an increased degree of convenience for the patients. Additionally, the irradiation treatments need to take place a minimum and maximum number of times per week (i.e. not necessarily every day), which additionally adds to the problem complexity. Finally, we aim at minimizing the idle times of the main resource – the particle accelerator – while simultaneously minimizing time window violations.

The base problem of scheduling recurring radiotherapy treatment activities has already been fairly studied in the literature. While some papers only focus on the assignment of treatment days and neglect the scheduling of starting times on each day (e.g. [5], [6]), others schedule the daily treatment activities to time slots with a predefined duration of e.g. 15 or 30 minutes ("block scheduling", e.g. [1], [2]). Lately, Maschler et al. have proposed a more detailed scheduling approach

* Corresponding author.

to solve the advanced radiotherapy scheduling problem arising in ion beam facilities using both a GRASP and an iterated greedy approach [3]. They incorporate both a day and time assignment phase, but do not deal with alternative resources or optional activities. Petrovic et al. [4] have first used population-based metaheuristics to schedule exact starting times without considering continuity in the daily start of the treatments for each patient.

The large variation in treatment durations and the strong competition for the resources in our case highly suggests a detailed scheduling approach, yielding exact, "to-the-minute" treatment starting times. Therefore, we design two construction heuristics that use classical priority rules known from the literature as well as more specific rules tailored to the problem at hand: The first heuristic schedules activities chronologically, while the second heuristic allows to fill availability gaps occurring from non-availability periods on the resources. In order to reduce penalties from time window violations and thereby increase feasibility, we further analyse repair strategies. Additionally, we develop a local search based metaheuristic solution approach based on the constructive scheduling schemes. Our main focus lies on the efficient usage of the bottleneck resource – the particle accelerator – while simultaneously minimizing the violation of soft time window constraints. Finally, the underlying chronological scheduling approach necessitates the formulation of an LP model to evaluate stable time violation penalties after the schedule construction has finished. First computational results on small and medium sized real world inspired instances are promising.

Keywords: Radiotherapy Scheduling, Metaheuristics, List Scheduling, Optional Activities, Alternative Resources, Stable Activity Times and Time Windows

References

1. Conforti, D., Guerriero, F., Guido, R.: Optimization Models for Radiotherapy Patient Scheduling. In: 4OR 6 (3), pp. 263–278 (2008)
2. Legrain, A., Fortin, M.A., Lahrichi, N., Rosseau, L.M.: Online Stochastic Optimization of Radiotherapy Patient Scheduling. In: Health Care Management Science 18 (2), pp. 110–123 (2015)
3. Maschler, J., Riedler, M., Stock, M., Raidl, G.R.: Particle Therapy Patient Scheduling: First Heuristic Approaches. In: Burke, E.K. et al. (eds) PATAT 2016: Proceedings of the 11th International Conference of the Practice and Theory of Automated Timetabling, pp. 223–244 (2016)
4. Petrovic, D., Morshed, M., Petrovic, S.: Multi-objective Genetic Algorithms for Scheduling of Radiotherapy Treatments for Categorised Cancer Patients. In: Expert Systems with Applications 38 (6), pp. 6994–7002 (2011)
5. Petrovic, S., Leite-Rocha, P.: Constructive and GRASP Approaches to Radiotherapy Treatment Scheduling. In: Ao, S. (ed.) Advances in Electrical and Electronics Engineering (IAENG), Special Edition of the World Congress on Engineering and Computer Science 2008, pp. 192–200. IEEE Computer Society (2008)
6. Sauré, A., Patrick, J., Tyldesley, S., Puterman, M.L.: Dynamic Multi-appointment Patient Scheduling for Radiation Therapy. In: European Journal of Operational Research 223 (2), pp. 573–584 (2012)

Tabu Search and solution space analyses. The job shop case.

Czesław Smutnicki, Wojciech Bożejko

Faculty of Electronics, Wrocław University of Science and Technology,
Wrocław, Poland
{czeslaw.smutnicki, wojciech.bozejko}@pwr.edu.pl

We provide new results of theoretical as well as experimental investigations of so called landscape of the discrete solution space for the job-shop scheduling problem. The problem is the leading, strongly NP-hard case from the scheduling theory with many excellent practical applications, already for the makespan criterion, not restricting our considerations to the mentioned one, [4]. The exceptional hardness of the problem can be justified by the well-known job-shop benchmark ft10 stated in 1963, that has only (!) 10 machines and 100 operations, and which had to wait 26 years to be solved by the branch-and-bound scheme. That's why, a huge number of job-shop approximate algorithms has been developed by years as a reasonable alternative for exact methods, expressing various degrees of the success, [1]. In the job-shop literature one can find many various approaches, beginning from B&B schemes, through approximation schemes, up to GA,TS, SA, and other straight and/or hybrid metaheuristic constructions.

In the nineties, Tabu Search (TS) approach made the breakthrough in thinking about efficient approximate solution methods, [3]. The algorithm TSAB, designed in 1993, [6] appeared among a few TS procedures dedicated for the job-shop. Surprisingly, it found optimal solution of ft10 in a few seconds and provided, for instances up to 2,000 operations, solutions of very high accuracy in a time of minutes on a standard PC. TSAB has been developed creatively, combining the *block approach* with other theoretical properties known in the scheduling. After the primal and the most spectacular success of this TS implementation, there have been designed several further algorithms for the flow-shop, hybrid flow-shop, and flow-shop buffer-constrained problems. Amazing properties of these algorithms remained unexamined till now, although many authors by brute force implemented these ideas without deeper analysis of their usefulness, [9]. Following the common usage the question "why TS is so good?" gets the particular significance. Capricious behaviour of approximate methods, already on standard benchmarks, incline scientists to define and identify factors of the instance hardness, which allow one to differentiate hard cases from easy. Another research stream examines nature of the solution space and the landscape, seeking properties responsible for the success/failure of an algorithm, [5]. We hope, that understanding strange properties of the solution space may explain the reasons of TS successes.

Theoretical research refers to various measures of the distance between solutions of the job-shop problem perceived as a composition of permutations. They uses metrics based on Cayley, Ulam, Kendall, Hamming distances between component permutations and the relative error of the goal function value. Theoretical distribution of the measure is also shown. In the experimental research we examine correlation between criterion value and the distance in the space and distribution of local extremes located on search trajectories in case of various solution algorithms. Roughness of the landscape has been defined formally and verified. Experimental distributions of relative distance to the optimal (best) solution found for various strategies used in the approximation algorithms are also provided by using common job-shop benchmarks. The interpretation of the space throw new light on the process of solving hard combinatorial optimization problems as well as on Tabu Search (TS) phenomenon. We hope that the study not only will explain the path of TS towards the success in the considered case, but also detect vital factors and provide insights for future designers of solution algorithms for hard discrete optimization problems, [7].

In the research we analysed, among others, the structure of the job-shop solution space in the context of new theoretical results as well as experimental findings, especially for: various classes of the schedules, distance measure between solutions, solution feasibility ratio, modelling redundancy, distribution of solutions in the space, distribution of local extrema, transformation of the space with dimensions reduction, space landscape, space size, space simulation, trajectories going through the space. All considerations are legitimized by suitable theoretical findings and illustrated by results of experimental numerical tests, with the use of sequential/parallel computing environments, [2,8].

References

1. Błażewicz J.. Domschke W. and Pesh E. (1996) The job shop scheduling problem. Conventional and new solution techniques. *European Journal of Operational Research*, 1-33.
2. Bożejko W. (2010), A new class of parallel scheduling algorithms, Oficyna Wydawnicza PWr, Wrocław, Poland.
3. Glover F. and Laguna M. (1997) Tabu search. Kluwer Academic Publishers. Massachusetts USA
4. Jain A.S. and Meeran S.. (1999) Deterministic job-shop scheduling: Past, present and future. *European Journal of Operational Research* 113. 390-434.
5. Mattfeld D.C., Bierwirth C. and Kopfer H. (1999) A search space analysis of the job shop scheduling problem. *Annals of Operations Research* 86. 441-453.
6. Nowicki E. and Smutnicki C. (1996) A fast tabu search algorithm for the job-shop problem. *Management Science* 42. 6. 797-813.
7. Smutnicki, C. (2011) Optimization technologies for hard problems., in: Fodor J., Klempous R., Araujo C. P. S. (eds.), *Recent advances in intelligent engineering systems.* Berlin, Heidelberg, Springer, 2011. s. 79-104.
8. Ten Eikelder H.M.M.. Aarts B.J.M.. Verhoeeven M.G.A.. Aarts E.H.L.. (1999) Sequential and paralled local search algorithms for job shop scheduling. In: Voss S.. Martello S.. Osman I.H.. Roucairol C. (eds.). *Meta-Heuristic: advances and Trends in Local Search Paradigms for Optimization.* Kluwer Academic Publishers. Norwell. Massachusetts. 359-371.
9. Watson J.P., Beck J.C., Howe A.E. and Whitley L.D. (2003) Problem difficulty for tabu search in job-shop scheduling. *Artificial Intelligence* 143. 189-217.

Variable Neighborhood Search for a Parallel Machine Scheduling Problem with Dependent Setup Times

Sarahi Baez[1], Belén Melián-Batista[2],
Francisco Angel-Bello[1], and Ada Alvarez[3] *

[1] Tecnológico de Monterrey
Escuela de Ingeniería y Ciencias
Monterrey, México
{a00818433,fangel}@itesm.mx
[2] Universidad de La Laguna
Departamento de Ingeniería Informática y de Sistemas
La Laguna, Spain
mbmelian@ull.es
[3] Universidad Autónoma de Nuevo León
Graduated Program in Systems Engineering
San Nicolás de los Garza, Nuevo León, México
ada.alvarezs@uanl.mx

This work proposes several variants of the Variable Neighborhood Search metaheuristic [5] for solving a parallel machine scheduling problem with dependent setup times. In this problem there are n independent jobs to be processed in m identical machines. Each job has an associated processing time p_j and each machine has associated setup times s_{ij} for processing job j after job i, with $s_{ij} \neq s_{ji}$, in general. There is a setup time s_{0j} for processing the first job on each machine. Each machine can process a job at a time and all machines have to be used. The aim of the problem is to assign jobs to machines and to determine the order in which jobs have to be processed on the machines in such a way that the sum of the completion times is minimized. That is, the objective is to minimize the Total Completion Time (TCT).

Little research has been done when parallel machines and dependent setups are considered. Bettayeb et al. [3] minimize the weighted flow time on a parallel machine system with family set-up times. They obtain lower bounds for a B&B algorithm. Nessah et al. [6] study a parallel machine scheduling problem with sequence-dependent set-up times and precedence constraints with the objective of minimizing the TCT. They solve small instances using a B&B algorithm, while for larger instances use the limited discrepancy search heuristic. For a similar problem, Gacias et al. [4] propose dominance conditions and define an exact B&B procedure and a climbing discrepancy search heuristic.

To the best of our knowledge, Baez et al. [2] is the only published work addressing the problem at hand. They proposed two mathematical formulations for the problem which have a better performance than a classical formulation

* This work has been partially funded by the Spanish Ministry of Economy and Competitiveness with FEDER funds (project TIN2015-70226-R).

based on m-Travelling Salesman Problem, consuming less computational time and solving to optimality instances up to 50 jobs.

The main contribution of this work is to propose the first metaheuristic approach to solve the addressed problem, which will allow to solve larger instances in short computational times. Particularly, we design and implement a General Variable Neighborhood Search and a Random Variable Neighborhood Decent.

We use classical movements to define neighborhoods, such as inter and intra machine movements of jobs. However, it should be remarked that when the objective function is to minimize the total completion time, local movements impact the completion time values of a large number of jobs, then the direct evaluation of a simple movement is, in general, very time-consuming. For this reason we develop efficient strategies to explore the defined neighborhoods.

In order to test our algorithms, we have considered two groups of instances from the literature; the one proposed by Vallada and Ruiz [7] and the one generated by Avalos-Rosales [1], using the same procedure of the previous group. Note that these instances were created for unrelated parallel machines. Given the fact that we are working with identical machines, we have used the data of the first machine in each instance. We have compared the obtained results with the bounds provided by the mathematical formulations developed by Baez el at [2].

References

1. O. Avalos-Rosales. *Secuenciación en máquinas paralelas no relacionadas con tiempos de preparación y tareas de mantenimiento preventivo. Ph. D Thesis.* Graduate Program in Systems Engineering. FIMA, UANL, 2014.
2. S. Baez, F. Angel-Bello, and A. Alvarez. Time-dependent formulations for minimizing total completion time in a parallel machine scheduling problem with dependent setup times. In *8th IFAC Conference on Manufacturing Modelling, Management and Control MIM 2016 Troyes, France, 2830 June 2016*, volume 49, pages 857 – 862, 2016.
3. B. Bettayeb, I. Kacem, and K.H. Adjallah. An improved branch-and-bound algorithm to minimize the weighted flowtime on identical parallel machines with family setup times. *Journal of Systems Science and Systems Engineering*, 17(4):446–459, 2008.
4. B. Gacias, C. Artigues, and P. Lopez. Parallel machine scheduling with precedence constraints and setup times. *Computers and Operations Research*, 37(12):2141–2151, 2010.
5. N. Mladenovic and P. Hansen. Variable neighborhood search. *Computers and Operations Research*, 24(11):1097–1100, 1997. cited By 1336.
6. R. Nessah, C. Chu, and F. Yalaoui. An exact method for pm / sds, ri / i = 1n ci problem. *Computers and Operations Research*, 34(9):2840–2848, 2007.
7. E. Vallada and R. Ruiz. A genetic algorithm for the unrelated parallel machine scheduling problem with sequence dependent setup times. *European Journal of Operational Research*, 211(3):612–622, 2011.

Optimization Networks for Integrated Machine Learning

Michael Kommenda, Andreas Beham,
Bogdan Burlacu, Johannes Karder,
Gabriel Kronberger, and Michael Affenzeller

Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria
Softwarepark 11, 4232 Hagenberg, Austria
michael.kommenda@fh-hagenberg.at

Extended Abstract

Machine learning enables computers to learn from and make predictions on data. A common task in machine learning is regression analysis where a model describing the relationship between several independent and one dependent variable is built. Another important task is feature subset selection [1] that determines which of the available independent variables should be used in the model. Both problems are interrelated in the sense that only if the most appropriate feature subset is selected, the resulting regression model achieves optimal prediction accuracy.

Whenever multiple, interrelated and dependent machine learning problems are considered in combination we use the term integrated machine learning. Integrated machine learning problems, consisting of at least two interrelated subproblems, can be solved using the concept of optimization networks.

Optimization networks are a general framework to solve interrelated problems holistically [2]. This is enabled by combining the individual subproblems through so-called orchestrators. Orchestrators define how individual subproblems interact and influence each other. Accordingly, an optimization network consists of multiple nodes, each representing a subproblem and the corresponding solver, that are connected by orchestrators.

An example for integrated machine learning is the problem of learning the most accurate linear prediction model on data containing 10 independent variables and one dependent variable. In total it is possible to create 1024 (2^{10}) different linear models, ranging from the most simplistic model without any variables at all to the most complex one that contains all available input variables. In this example an exhaustive search of all possible feature subsets is still feasible due to the low number of independent variables. However, in practice the size of the data does not allow an exhaustive enumeration of all possible feature

The authors gratefully acknowledge financial support by the Austrian Research Promotion Agency (FFG) within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532.

subsets, as there are 2^n possible combinations for a dataset with n independent variables.

This integrated machine learning task can be represented as an optimization network. The feature subset selection can be modeled as binary optimization problem, where the binary vector encodes the selected feature subset. The regression problem of creating a linear model can be solved deterministically using linear regression. The orchestrator passes the binary vector to the linear regression algorithm and triggers model creation. The prediction quality of the resulting model is handed back to the selection problem and acts as a quality indicator for the concrete subset. The depicted optimization network is solved using a sequential optimization approach [3], where each selected feature subset triggers the linear regression algorithm. However, depending on the relationship between the subproblems other more collaborative approaches are suitable as well.

A benefit of using optimization networks to model integrated machine learning problems is that the solvers for the individual subproblems can be easily exchanged. For example, the feature subset selection problem can be solved by exhaustive search. If that becomes infeasible any optimization algorithm that works with binary encodings can be used, such as local search, variable neighborhood search, or genetic algorithms. Furthermore, the composition of networks consisting of individual subproblems enables the reuse of existing algorithms and problems, thus reducing the formulation, definition, and implementation effort. Another important aspect is that certain combinations of subproblems can only be solved in unison to achieve globally valid optimization results due to conflicting individual optimization objectives.

To the best of our knowledge optimization networks have only been applied to combinatorial optimization problems, mostly in the context of production and logistics [2]. In this contribution we demonstrate the suitability of optimization networks for integrated machine learning problems on the basis of two case studies. In the first case study, we use an optimization network that combines feature selection, hyperparameter optimization, and regression analysis. The second case study combines goal seeking and regression analysis, where optimal input parameter values have to be calculated to reach specified target goals.

References

1. Guyon, I., Elisseeff, A.: An introduction to variable and feature selection. Journal of machine learning research **3** (2003) 1157–1182
2. Hauder, V.A., Beham, A., Wagner, S.: Integrated performance measurement for optimization networks in smart enterprises - accepted for publication. In: OTM Confederated International Conferences" On the Move to Meaningful Internet Systems", Springer (2016)
3. Beham, A., Fechter, J., Kommenda, M., Wagner, S., Winkler, S.M., Affenzeller, M.: Optimization strategies for integrated knapsack and traveling salesman problems. In: International Conference on Computer Aided Systems Theory, Springer (2015) 359–366

Evaluating Parallel Minibatch Training for Machine Learning Applications

Stephan Dreiseitl

Dept. of Software Engineering
FH Upper Austria, A-4232 Hagenberg, Austria

Over the last decade, the coinciding rise of three factors has led to revolution in data analytics. These factors are the exponential growth of available data, advances in machine learning algorithms, and ubiquitous and cheap computing resources, either via cloud computing or GPU technology. While this revolution has given rise to systems that rival human performance on auditory and visual perception tasks [1], several of the underlying algorithms (most notably the optimizers that implement the learning in the systems) are sequential in nature, and thus form an inherent limitation to the speedups possible even with parallel hardware.

While optimization methods traditionally employed in machine learning algorithms operate iteratively, performing several passes over the entire dataset, this has become harder as increasing data volumes may not fit into the limited memories of special-purpose hardware, such as GPUs. This problem gave rise to stochastic versions of algorithms (such as stochastic gradient descent), where updates are performed in a online manner for each data point, and to *minibatches*, where limited portions of the entire dataset are processed sequentially.

The algorithmic task of training machine learning models on minibatches is interesting and highly relevant in a related, but entirely different setting: privacy-preserving distributed machine learning [2]. In this field, the research interest is on building data models when the data cannot be pooled, mostly for security or privacy reasons.

It is tempting to view model training on minibatches as a trivial way to parallelize and distribute machine learning algorithms: Train several (distributed) models in parallel, each on their own minibatch, and then somehow combine these models. It is exactly this model combination that is, theoretically, far from trivial, as most parametrizations of trained machine learning models represent minima of error surfaces. It is initially not clear how the positions of several minima, each corresponding to one minibatch model, can be combined in a meaningful manner into a minimum corresponding to a better model of the entire dataset.

Recently, substantial progress has been made on this problem, most notably with a proof that minibatch models trained with stochastic gradient descent on convex error surfaces can be combined merely by averaging their parametrizations [3]. The objective of this paper is to expand on this averaging idea by iterating the process, and to evaluate its performance also on non-convex optimization problems trained with higher order methods, such as conjugate gradient and quasi-Newton algorithms. The code in Algorithm 1 gives a top-level view of this approach.

Algorithm 1 Parallel (distributed) minibatch training

Split data into M minibatches patch$_1$,...,patch$_M$ // omit in distributed setting
Randomly initialize θ (model parameters)
for $k = 1$ to N **do**
  for $j = 1$ to M **do in parallel**
    β_j = trainmodel(θ, patch$_j$) // obtain new parameters β_j
  end parallel for
  θ =mean($\beta_1, \ldots, \beta_M$) // communication overhead in distributed setting
end for

We investigate the effect of parameter-averaging parallel minibatch training on two standard machine learning tasks, one representing a convex optimization problem relevant to privacy-preserving machine learning in medical contexts (training a logistic regression model), and one representing a non-convex optimization problem relevant to large-scale parallel machine learning (training an autoencoder).

Table 1 shows a performance summary of parallel minibatch training for a sparse autoencoder [4] on a sample of 8×8 pixel patches taken the CIFAR-10 dataset. The total number of minimizer iterations was set to 400. Therefore, every call to trainmodel in Algorithm 1 used $400/N$ minimizer iterations. One can observe the viability of the proposed approach, as the average reconstruction error (over all test patches) increases only slightly when combining minibatch models.

Table 1. Mean reconstruction error of 5 000 test patches for an autoencoder trained on 10 000 patches according to Algorithm 1, divided into $M = 10$ minibatches, for varying number of outer loop iterations N. For comparison, the first entry gives the mean reconstruction error of a model trained on the full dataset.

full model	$N = 10$	$N = 20$	$N = 30$	$N = 40$
0.53378	0.55822	0.56016	0.58246	0.59408

The full paper will present the results of a more thorough investigation of minibatch training for logistic regression and sparse autoencoder models.

References

1. Wan, L., Zeiler, M., Zhang, S., LeCun, Y., Fergus, R.: Regularization of neural networks using DropConnect. In: Proceedings of the 30th International Conference on Machine Learning. (2013) 1058–1066
2. Friedman, A., Schuster, A.: Data mining with differential privacy. In: Proceedings of the 16th ACM SIGKDD International Conference on Knowledge discovery and data mining. (2010) 493–502
3. Zinkevich, M., Weimer, M., Li, L., Smola, A.: Parallelized stochastic gradient descent. In: Advances in Neural Information Processing Systems 23. (2010) 2595–2603
4. Ng, A.: CS294A lecture notes: Sparse autoencoder. Stanford University (2011)

A Fair Performance Comparison of Different Surrogate Optimization Strategies

Bernhard Werth[1,2] and Erik Pitzer[1]

[1] Heuristic and Evolutionary Algorithms Laboratory
School of Informatics, Communications and Media
University of Applied Sciences Upper Austria, Hagenberg Campus
[2] Institute for Formal Models and Verification
Johannes Kepler University, 4040 Linz,
Altenberger Straße 68, Austria

Surrogate models in the widest sense are (statistical) models used to approximate problems, that are expensive or difficult to evaluate. These problems include simulation code, physical experiments or problem functions with discontinuities, local optima or plateaus, that cause difficulties for optimization algorithms [1]. An approximation of such expensive functions can serve multiple purposes. An easier to evaluate model can be used in optimization tasks in order to decrease computational time and budget needed or to make optimization feasible at all in the first place. Additionally the construction of a surrogate model can create an improved understanding of the original problem and the processes involved. This work will concern itself with the comparison of different surrogate models, sampling plans and modelling approaches which is of special interest if surrogate models shall be used in combination with existing heuristic optimization algorithms.

Widely used types of models are *polynomial and linear response surfaces*, *Gaussian process models* [7] or *Radial basis functions* [4]. Additionally, function approximations via regression with *artificial neural networks* (ANNs) and *support vector machines* (SVMs) have been proposed [2]. As a consequence a more generalized form of regression (i.a. *symbolic regression*) could be used as a surrogate model. These models vary not only in the type of regression function they are using, but also in whether they are used as *global* models where a single model is created from all available data points or as *local* models which only hold sway over specific areas [3] of the search space and use only subsets of the previously sampled points. Another major difference in the use of surrogate model assisted optimization lies in the selection of sampling points, where the underlying expensive fitness function is evaluated. Wang and Shan [8] identify three main strategies. In the *sequential* approach, all sample points are evaluated at the beginning, an optimization is performed on the surrogate and the best found solution is evaluated to ensure validity. The *adaptive* approach, evaluates new samples during the optimization process to continuously improve the model and the *direct sampling* approach where additional information from the meta model like the *Expected Improvement* [5] is used to select the next sample point.

Several authors [6] already gave comprehensive reviews about the uses and approaches of surrogate modelling. Many papers presenting new strategies or algorithms tend to compare their new approach to a "standard" one. Unfortunately these standard approaches are rarely, if ever, the same or based on the same implementation. This work focuses on reimplementing the before mentioned surrogate functions, search space localities and sampling strategies within a single optimization framework *HeuristicLab* in order to allow a fair and equal comparison. Comparisons will be made on a set of widely used benchmark functions with variable dimensionality in order to assess the performance of different methods in high dimensional scenarios. The main focus lies on the compatibility of surrogate evaluation with existing gradient free optimization approaches like *genetic algorithms*, *evolutionary strategies*, *simulated annealing* and *particle swarm optimization* is explored.

References

1. Alexander E.I. Brownlee, John R. Woodward, and Jerry Swan. Metaheuristic design pattern: Surrogate fitness functions. In *Proceedings of the Companion Publication of the 2015 Annual Conference on Genetic and Evolutionary Computation*, GECCO Companion '15, pages 1261–1264, New York, NY, USA, 2015. ACM.
2. Stella M Clarke, Jan H Griebsch, and Timothy W Simpson. Analysis of support vector regression for approximation of complex engineering analyses. *Journal of mechanical design*, 127(6):1077–1087, 2005.
3. Israel Cruz-Vega, Mauricio Garcia-Limon, and Hugo Jair Escalante. Adaptive-surrogate based on a neuro-fuzzy network and granular computing. In *Proceedings of the 2014 Annual Conference on Genetic and Evolutionary Computation*, pages 761–768. ACM, 2014.
4. Yibo Ji and Sujin Kim. Regularized radial basis function models for stochastic simulation. In *Proceedings of the 2014 Winter Simulation Conference*, WSC '14, pages 3833–3844, Piscataway, NJ, USA, 2014. IEEE Press.
5. Donald R Jones, Matthias Schonlau, and William J Welch. Efficient global optimization of expensive black-box functions. *Journal of Global optimization*, 13(4):455–492, 1998.
6. Timothy W Simpson, Andrew J Booker, Dipankar Ghosh, Anthony A Giunta, Patrick N Koch, and R-J Yang. Approximation methods in multidisciplinary analysis and optimization: a panel discussion. *Structural and multidisciplinary optimization*, 27(5):302–313, 2004.
7. Timothy W Simpson, Timothy M Mauery, John J Korte, and Farrokh Mistree. Kriging models for global approximation in simulation-based multidisciplinary design optimization. *AIAA journal*, 39(12):2233–2241, 2001.
8. G Gary Wang and Songqing Shan. Review of metamodeling techniques in support of engineering design optimization. *Journal of Mechanical design*, 129(4):370–380, 2007.

Genetic Algorithms with Persistent Data Structures – A Perfect Match

Erik Pitzer and Michael Affenzeller

Heuristic and Evolutionary Algorithms Laboratory
School of Informatics, Communications and Media
University of Applied Sciences Upper Austria, Hagenberg Campus
Softwarepark 11, 4232 Hagenberg, Austria
{erik.pitzer,michael.affenzeller}@fh-hagenberg.at

1 Introduction

Genetic and other population-based algorithms are implemented in procedural programming language using mutable data structures. There are many different types of algorithms where a population of individuals is repeatedly modified and combined with each other to incrementally arrive at better solution candidates.

When it comes to the analysis of their progress however, typical approaches quickly become unfeasible as the sheer amount of data grows very fast. In the recent past however, new developments in the area of data structures have bestowed us with so called persistent or purely-functional data structures [4] and allow a new paradigm of dealing with data.

At first, these data structures seem counterintuitive as they are immutable. Every change yields a whole new "copy", which seems wasteful and unsuitable for population-based algorithms as *all* of the data has to be copied on modification. In reality, however, typical implementations rely on the fact that these data structures also harbor *immutable data values*. That entails, that copying is not necessary as the contained data cannot change and therefore, the new "copy" can share part of its structure with the original version.

Superficially, this barely brings them on par with mutable data structures. The mutation operation entails approximately the same (or slightly more) work than a modification of classical data structures. However, changes to data structures are now full snapshots, while the actual *space* cost is much less. This makes it feasible to keep a history of all kinds of changes at a greatly reduced cost.

A simple example of structure sharing is shown in Figure 1, where an immutable list A can be prepended with an additional value. The resulting list is now known as B and shares most of its structure with A.

2 Materials and Methods

Population-based algorithms usually work on vectors of individuals which in turn are vectors. Immutable and structure-sharing vectors with near-constant indexing and updating costs are available as e.g. Hash Array Mapped Tries (HAMT) [1] and are the standard vector implementation of the Clojure Programming Language [3]. Recently, also support for practically constant-space

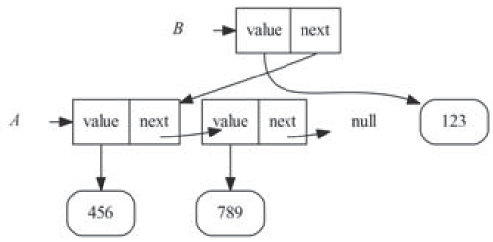


Fig. 1. Example of Shared Structure in Singly Linked list

splitting and joining of vectors in the form of Relaxed Radix Based Trees (RRB-Trees) [2] have become possible.

Many genetic operations on individuals or populations can be formulated as single or multiple point modifications for mutations or as a series of split and join operations in the case of genetic crossover. With the help of these data structures keeping track of *all* changes becomes convincingly cheap.

For example, updating a single element in a HAMT causes $log_{32}N$ memory accesses. In an RRB-Tree the cost of e.g. joining two vectors is $m^2/\lg m \cdot \lg N$ where m is the node size (typically 32) and N is the size of the vector. In other words the update cost is on the order $\mathrm{O}(\log N)$ which has the same complexity as a single point modification operation both in time and space.

3 Results

By incorporating these data structures into heuristic optimization platforms, such as HeuristicLab [5] many new possibilities for cheaply tracking evolutionary algorithms become feasible. New algorithm variants that not only focus on the current situation but can "backtrack", similar to trajectory-based algorithms are possible. We have implemented a prototype that uses these data structures and can track large populations with long evolution durations with minimal effort. Current results show very light memory usage and will enable many new analysis methods.

Acknowledgements The work described in this paper was performed within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532 funded by the Austrian Research Promotion Agency (FFG).

References

1. Bagwell, P.: Ideal hash trees. Tech. rep., École Polytechnique Fédéerale de Lausanne (2001)
2. Bagwell, P., Rompf, T.: Rrb-trees: Efficient immutable vectors. Tech. rep., École Polytechnique Fédéerale de Lausanne (2011)
3. Hickey, R.: The clojure programming language. URL `http://clojure.org` (2006)
4. Okasaki, C.: Purely functional data structures. Cambridge University Press (1999)
5. Wagner, S.: Heuristic Optimization Software Systems - Modeling of Heuristic Optimization Algorithms in the HeuristicLab Software Environment. Ph.D. thesis, Johannes Kepler University, Linz, Austria (2009)

Offspring Selection Genetic Algorithm Revisited: Improvements in Efficiency by Early Stopping Criteria in the Evaluation of Unsuccessful Individuals

Michael Affenzeller, Bogdan Burlacu, Stephan Winkler, Michael Kommenda, Gabriel Kronberger, and Stefan Wagner

Heuristic and Evolutionary Algorithms Laboratory
School of Informatics, Communications and Media
University of Applied Sciences Upper Austria, Hagenberg Campus
Softwarepark 11, 4232 Hagenberg, Austria
michael.affenzeller@fh-hagenberg.at

1 Extended Abstract

Offspring selection (OS) [1] is a generic extension to the general concept of a genetic algorithm [2], [3] which includes an additional selection step after reproduction: The fitness of an offspring is compared to the fitness values of its own parents in order to decide whether or not a the offspring solution candidate should be accepted as a member of the next generation or not. The origins of offspring selection were laid in the SEGA algorithm [4] where a certain user defined birth surplus of individuals is generated in order to accept the best individuals as members of the next generations in a coarse grained parallel genetic algorithm. In the successor of SEGA, the SASEGASA algorithm [5], offspring selection was already inherently included as selection procedure in the algorithm's demes, which are called village populations within SASEGASA. The implementation of this selection procedure within a single population GA was published as offspring selection the first time in 2005 [1].

Since then offspring selection has been applied successfully for combinatorial optimization problems, simulation based optimization as well as in a lot of symbolic regression and symbolic classification applications when being combined with genetic programming. Summaries of offspring selection applications in various fields are given for example in [6], [7], and [8].

After a short summary of the the classical offspring selection GA the full paper will present an algorithmic extension that aims to improve the runtime characteristics of the method significantly without losses in terms of quality. The efficiency gain of the method is achieved by the integration of early termination criteria in the evaluation of solution candidates that are expected to fail the offspring success criterion. This strategy is evaluated for symbolic regression and symbolic classification using benchmark problems that are solved using genetic programming with OS. For such data based modeling problems the ratio of not successful solution candidates is usually very high, especially for large scaled data analysis problems where the runtime bottleneck is the evaluation function and the ratio of non-successful solution candidates is especially high due to the application of strict offspring selection [6]. As the focus of this algorithmic extension is to improve runtime performance, this increase has to be quantified. Computation time on a certain machine is a practical but often not objective measure as the results depend on the concrete implementation and on the framework and its overhead. Especially in the field of stochastic optimization where solution evaluation is often the most time consuming step, the effort of the algorithm is measured on the basis of solution evaluations. As the algorithmic enhancement proposed in this work aims to achieve savings in runtime by partial solution evaluation, effort will be measured as the fraction of training data samples that are actually evaluated.

Acknowledgments

The work described in this paper was conducted within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532 funded by the Austrian Research Promotion Agency (FFG).

References

1. Affenzeller, M., Wagner, S., Winkler, S.: Ga-selection revisited from an es-driven point of view. In Mira, J., Alvarez, J.R., eds.: Artificial Intelligence and Knowledge Engineering Applications: A Bioinspired Approach. Volume 3562 of Lecture Notes in Computer Science., Springer (2005) 262–271
2. Holland, J.H.: Adaption in Natural and Artifical Systems. University of Michigan Press (1975)
3. Goldberg, D.E.: Genetic Algorithms in Search, Optimization and Machine Learning. Addison Wesley Longman (1989)
4. Affenzeller, M.: A new approach to evolutionary computation: Segregative genetic algorithms (SEGA). In Mira, J., Prieto, A., eds.: Connectionist Models of Neurons, Learning Processes, and Artificial Intelligence. Volume 2084 of Lecture Notes in Computer Science., Springer (2001) 594–601
5. Affenzeller, M., Wagner, S.: SASEGASA: An evolutionary algorithm for retarding premature convergence by self-adaptive selection pressure steering. In Mira, J., Alvarez, J.R., eds.: Computational Methods in Neural Modeling. Volume 2686 of Lecture Notes in Computer Science., Springer (2003) 438–445
6. Affenzeller, M., Winkler, S., Wagner, S., Beham, A.: Genetic Algorithms and Genetic Programming - Modern Concepts and Practical Applications. Chapman & Hall / CRC (2009)
7. Affenzeller, M., Winkler, S.M., Kronberger, G.K., Kommenda, M., Burlacu, B., Wagner, S.: Gaining deeper insights in symbolic regression. In Riolo, R., Moore, J.H., Kotanchek, M., eds.: Genetic Programming Theory and Practice XI. Number 10. 1 edn. Springer (2014) 175–190
8. Affenzeller, M., Beham, A., Vonolfen, S., Pitzer, E., Winkler, S.M., Hutterer, S., Kommenda, M., Kofler, M., Kronberger, G.K., Wagner, S.: Simulation-based optimization with heuristiclab. In Mota, M.M., Mota, I.D.L., Serrano, D.G., eds.: Applied Simulation and Optimization. Number 1. Springer (2015) 3–38

Analysis of Schema Frequencies in Genetic Programming

Bogdan Burlacu[1,2], Michael Affenzeller[1,2], Michael Kommenda[1,2], Gabriel Kronberger[1], and Stephan Winkler[1]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, Softwarepark 11, 4232 Hagenberg
bogdan.burlacu@fh-hagenberg.at

[2] Institute for Formal Models and Verification
Johannes Kepler University, Altenbergerstr. 69, 4040 Linz

Extended Abstract

Schema theorems provide a mathematical foundation for the ability of genetic programming (GP) to find good solutions to problems from many fields. A *schema* represents a genotypic template that partitions the search space into subspaces of programs, characterized by distinct structural properties. In this paper we adopt the schema definition of Poli [1] with wildcards represented by the symbols $\{=, \#\}$, where '=' matches any internal node with the same arity and '#' matches any valid subtree. For example, the schema $(= \; x_1 \; \#)$ represents the subspace of all programs that consist of a function of two arguments, where the first argument is x_1 and the second argument can be any other subtree.

The main assumption is that GP solutions are formed from schemas with above-average fitness and low defining length, denoted as *building blocks*. In this context, genetic operators such as selection, crossover and mutation can be analyzed in terms of their effect on schema transmission probabilities from one generation to the next. Exact schema theorems have led to important insights such as new crossover operators for GP (one-point and uniform crossover), a size evolution equation for controlling bloat, more suitable problem representations or better population initialization methods [1]. However, schema theorems have some practical limitations. In typical scenarios the complexity of the equations makes it difficult keep track of all quantities involved [2]. This paper works around such limitations by using tree pattern matching to empirically measure schema frequencies in GP populations.

The implementation poses two specific challenges: firstly, our tree matching algorithm must support unordered trees with wildcards, in accordance to the adopted schema definition, and must be fast enough to enable the analysis of large GP populations. Secondly, we require a reliable method for finding relevant schemas to be matched against the population.

The authors gratefully acknowledge financial support by the Austrian Research Promotion Agency (FFG) within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532.

We overcome the first issue by implementing the bottom-up variant of the algorithm for the tree homeomorphism decision problem by Götz et al. [3], adjusted to enforce a stricter matching by requiring nodes to have the same parent, the same children and be on the same level in the tree.

We approach the second issue starting from a basic assumption: trees of common parents (ancestors) will share a common genetic template. We use genealogy graphs to record hereditary relationships and positional information about inherited subtrees [4]. In the case of crossover, two individuals with the same root parent will inherit the same overall structure. Their genotypes will differ only in the positions given by the crossover cutpoints. We produce schemas by replacing subtrees at cutpoint positions in the root parent with wildcards.

We tested the methodology using a standard benchmark problem[1] and offspring selection GP with a population of 500 individuals. Figure 1 shows the frequency and structure (in polish notation) of the top schemas from generations 5, 10, 15, 20 (shown in the plot legend in this order from top to bottom). We notice that schema frequency increases as the algorithm converges, and that the schemas capture formula terms such as x_1x_2, x_3x_4, x_5x_6, $x_3x_6x_{10}$. Therefore schemas identified by this method contain the relevant building blocks for the problem. The approach may be used to analyze premature convergence and loss of diversity, or to provide empirical validation of schema theoretic findings. A complete analysis will be given in the full version of this paper.

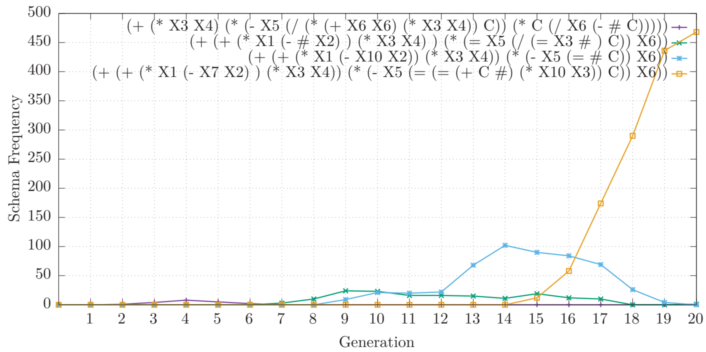


Fig. 1. Frequency of the most common schema at each generation.

References

1. Poli, R., McPhee, N.F.: General schema theory for genetic programming with subtree-swapping crossover: Part II. Evolutionary Computation **11** (2003) 169–206
2. Poli, R., Vanneschi, L., Langdon, W.B., McPhee, N.F.: Theoretical results in genetic programming: the next ten years? Genetic Programming and Evolvable Machines **11** (2010) 285–320
3. Götz, M., Koch, C., Martens, W.: Efficient algorithms for descendant-only tree pattern queries. Inf. Syst. **34** (2009) 602–623
4. Burlacu, B., Affenzeller, M., Winkler, S.M., Kommenda, M., Kronberger, G.K.: Methods for genealogy and building blocks analysis in genetic programming. In: Computational Intelligence and Efficiency in Engineering Systems. Number 5. Springer (2015) 61–74

[1] We used the Poly-10 benchmark $F(\mathbf{x}) = x_1x_2 + x_3x_4 + x_5x_6 + x_1x_7x_9 + x_3x_6x_{10}$.

Analysis and Visualization of the Impact of Different Parameter Configurations on the Behavior of Evolutionary Algorithms

Stefan Wagner[1], Andreas Beham[1,2], and Michael Affenzeller[1,2]

[1] Heuristic and Evolutionary Algorithms Laboratory
School of Informatics, Communications and Media - Campus Hagenberg
University of Applied Sciences Upper Austria
Softwarepark 11, 4232 Hagenberg, Austria
{swagner,abeham,maffenze}@heuristiclab.com

[2] Institute for Formal Models and Verification
Johannes Kepler University Linz
Altenbergerstr. 69, 4040 Linz, Austria

Extended Abstract

Evolutionary algorithms and in most cases metaheuristic optimization algorithms in general offer several parameters which can be changed in order to adapt an algorithm's search behavior. For example, in a simple genetic algorithm the population size, the number of generations, the mutation rate, the number of elite solutions, the selection scheme, and the crossover and mutation operators can be configured. These parameters offer a high degree of flexibility and make it possible to tune an algorithm according to a specific application scenario. However it is also well-known that the performance of evolutionary algorithms is very sensitive regarding these parameter values. Small changes of parameters often result in drastic changes of an algorithm's search characteristics. Additionally, many parameters strongly influence each other and therefore cannot be treated independently. Appropriate parameter tuning consequently is a non-trivial task and is of major importance when applying evolutionary algorithms [1].

Nevertheless, it is a surprising fact that parameter tuning is often not sufficiently considered. Many publications which describe the application of evolutionary algorithms on specific optimization problems do not provide any information about the way how the used parameter settings have been obtained. It seems that many researchers and especially newcomers in the field simply treat evolutionary algorithms as black boxes and choose an algorithm's parameter values rather unsystematically by trail and error. Thereby they miss the chance to gain deeper insights into the complex interplay of parameter configurations and

The work described in this abstract is part of the COMET project Heuristic Optimization in Production and Logistics (HOPL) #843532, funded by the Austrian Research Promotion Agency (FFG).

algorithm behavior which would help to identify and explore promising parameter settings in a more efficient way.

In order to improve this situation, a significant research focus has been put on automated parameter tuning and algorithm configuration in the evolutionary computation community within the last years. Methods such as the irace package [2] for example represent powerful algorithms to efficiently tune parameters of optimization algorithms for different problem instances or even problem types. However, although automated parameter tuning techniques help to find suitable parameter configurations, they usually do not provide suitable feedback on the interrelationship of parameter settings and algorithm behavior. Therefore, they do not help users to gain a better understanding of the applied optimization algorithm and of the impact of its parameters.

The goal of this contribution is to present an interactive analysis and visualization approach which helps users of evolutionary algorithms (especially newcomers or students) in the exploration of different parameter settings and in understanding their influence on algorithm behavior. We will extend our heuristic optimization environment HeuristicLab[1] in such a way, that algorithm performance characteristics (i.e. obtained solution quality, variation of solution quality and required effort) can be easily computed for large numbers of test runs. Then we will implement a new interactive run analysis chart in HeuristicLab, which enables users to explore and compare different parameter configurations regarding these performance values. Each parameter setting is thereby represented as a single data point of its associated performance measurements and convenient filtering and coloring makes it possible to analyze even a very large number of runs. By this means users can for example easily identify clusters of parameter configurations which result in similar algorithm behavior. In order to demonstrate the usability of our approach, we will also create and publish a large reference data set of test runs obtained with a canonical genetic algorithm and with an offspring selection genetic algorithm [3] for different instances of the traveling salesman problem and will present a comprehensive analysis of the influence of different parameter configurations on the behavior of these algorithms.

References

1. Eiben, A., Smit, S.: Parameter tuning for configuring and analyzing evolutionary algorithms. Swarm and Evolutionary Computation **1** (2011) 19–31
2. López-Ibáñez, M., Dubois-Lacoste, J., Pérez Cáceres, L., Birattari, M., Stützle, T.: The irace package: Iterated racing for automatic algorithm configuration. Operations Research Perspectives **3** (2016) 43–58
3. Affenzeller, M., Wagner, S.: Offspring selection: A new self-adaptive selection scheme for genetic algorithms. In Ribeiro, B., Albrecht, R.F., Dobnikar, A., Pearson, D.W., Steele, N.C., eds.: Adaptive and Natural Computing Algorithms. Springer Computer Series, Springer (2005) 218–221

[1] `http://dev.heuristiclab.com`

Local search metaheuristics with reduced searching diameter

Wojciech Bożejko[1], Czesław Smutnicki[1],
Mariusz Uchroński[1], Mieczysław Wodecki[2]

[1]Faculty of Electronics, Wrocław University of Science and Technology,
Wyb. Wyspiańskiego 27, 50-370, Wrocław, Poland
{wojciech.bozejko,czeslaw.smutnicki,mariusz.uchronski}@pwr.edu.pl
[2]Institute of Computer Science, University of Wrocław
Joliot-Curie 15, 50-383 Wrocław, Poland
mieczyslaw.wodecki@uwr.edu.pl

In the paper we present some methods of empirical research of optimization problems' solution space, for which solutions are represented by permutations. Sampling the feasible solutions set we determine a histogram of frequency of incidence of local minima measuring its distance to the neighborhood graph's center. On its basis we verify a statistical hypothesis on normal distribution occurrence of local minima. Due to this research we can significantly reduce the area of the searching process during a local search metaheuristics work, focusing the searching process on Big Valley. We propose an algorithm with changeable diameter of the search.

In many good optimization algorithms, exact ones as well as approximate, one take advantage of many, usually specific for the considered problem, properties of the cost function and the space of feasible solutions. Combinatorial optimization problems have no classical analytical properties, such as convexity or differentiability and they have a huge number of local extrema. Additionally, the size of the solution space grows very fast (relative to the size of the data) which excludes the application of 'brute force' methods. Therefore it is necessary to research the landscape of the solution space (fitness landscape) – connections between values of the cost function and distances in the space. There are several measures of distance for the permutations (Hamming, Spearman rank correlation, Kendall's tau, Cayley, Ulam) and some of them have a close relationship with moves usually used in the neighborhood generation inside local search metaheuristics. Fitness landscape is defined in the literature [3] as a triple $(\mathcal{S}, F, d)$, where $\mathcal{S}$ is a solution space, F cost function, and d distance measure between solutions. In addition, many advanced heuristic methods, e.g. paths relinking [2], are used to evaluate the distance between solutions. Such properties of fitness landscapes, for some scheduling problems, were described and applied in algorithms proposed in works of Smutnicki [4] and Bożejko [1]. The new knowledge about relationship between distances and cost function will be used in the method which we propose here.

The idea of the proposed tool is narrowing the search area and the use of this knowledge in the construction of neighborhood in the local search method, i.e. tabu search or simulated annealing. Firstly, we need to sample the solution space until a number of local extrema is found (e.g. hundred). This sampling can be done stochastically, or in a deterministic way during the first phase of the local search metaheuristic work – when the local search algorithm finds a new best solution, it is added to the local extrema 'sample' set. This is the first step. The second step determines the so-called central solution, a local extremum which has the shortest distance to the farthest element of the local extrema set. Then – the third step – we determine a histogram of frequency (distribution) of distances measured from the central solution to each element of the local extrema set. The distribution should be normal $\mathcal{N}(m, \sigma)$, and it can be checked by applying statistical test (e.g. Kolmogorov - Smirnov). From this research we have an average value m and standard deviation σ. So we can assume, that approximately 99.97% of local extrema lies between $m - 3\sigma$ and $m + 3\sigma$ from the central solution. The last step consists in researching, during the local search metaheuristics, only this area.

Preliminary numerical experiments done on the job shop scheduling problem confirm that such a method executes less need less number of steps to achieve the same quality of solutions, comparing to classical algorithm without the proposed mechanism.

References

1. Bożejko W. (2010), A new class of parallel scheduling algorithms, Oficyna Wydawnicza PWr, Wrocław, Poland.
2. Bożejko W. (2010) Parallel path relinking method for the single machine total weighted tardiness problem with sequence-dependent setups, Journal of Intelligent Manufacturing Volume 21 Issue 6, 2010, 777-785.
3. Burke K.E., Kendall G. (2005) (eds.) Search Methodologies. *Introductory Tutorials in Optimization and Decision Support Techniques*, Springer, 2005.
4. Smutnicki, C. (2011) Optimization technologies for hard problems., in: Fodor J., Klempous R., Araujo C. P. S. (eds.), *Recent advances in intelligent engineering systems.* Berlin, Heidelberg, Springer, 2011. s. 79-104.

Glucose Prognosis by Grammatical Evolution

J. Ignacio Hidalgo[1], J. Manuel Colmenar[2], G. Kronberger[3], and S.M. Winkler[3]

[1] Adaptive and Bioinspired Systems Group,
Universidad Complutense de Madrid, 28040 Madrid, Spain

[2] Rey Juan Carlos University
Tulipán s/n, 28933 Mstoles (Madrid), Spain

[3] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, Softwarepark 11, 4232 Hagenberg

Abstract

Type 1 Diabetes Mellitus is a chronic disease characterized by elevated blood glucose due to a lack of insulin and, only in Spain, affects over 600 thousand people. Patients with this disease need lifelong, both measure their glucose and insulin injected subcutaneously. In clinical practice, blood sugar can be measured by continuous glucose monitors and insulin is injected either manually or by continuous subcutaneous infuser or insulin pump. On the other hand, a completely autonomous glycemic control would require a predictive model to estimate the future progress of blood glucose. With this information, a control algorithm would determine the dose of insulin to be delivered by the insulin pump. Current predictive models only consider measurements under controlled conditions of patients, which in most cases do not reflect the real-life or the patient characteristics. Glucose value prediction as a function of the insulin and food intakes is a difficult task that diabetics need to do everyday.

Evolutionary Computation (EC) and Machine Learning (ML) had shown promising results in previous works [1]. In this work Grammatical Evolution (GE) techniques are applied for the prediction of glucose using the values measured by Continuous Monitoring Glucose systems. We obtain more reliable and individualized predictive models of the glucose regulatory system, eliminating restrictions such as linearity or limitation on the input parameters.

Taking glycemia, food intakes, levels of fatigue, stress, etc. .. as inputs, we can generate reliable predictive models of the levels of blood glucose. In the case of modeling the glycemia of diabetic patients with GE, the phenotype of an individual is the model expression for prognosis. We need to create a grammar to guide the optimization process towards a model expression for prediction. We apply a grammar which considers that the prediction for time t may depend on the previous values of glucose, carbohydrates ingestion and insulin injection following the work in [2]. We implemented the GE process in Java using the ABSys JECO library (https://github.com/ABSysGroup/jeco) using compilable phenotypes to speed up the evaluation of individuals.

Our goal is to identify models (predictors) for the following target variables that describe the future glucose values after 30, 60 90 and 120 minutes.The

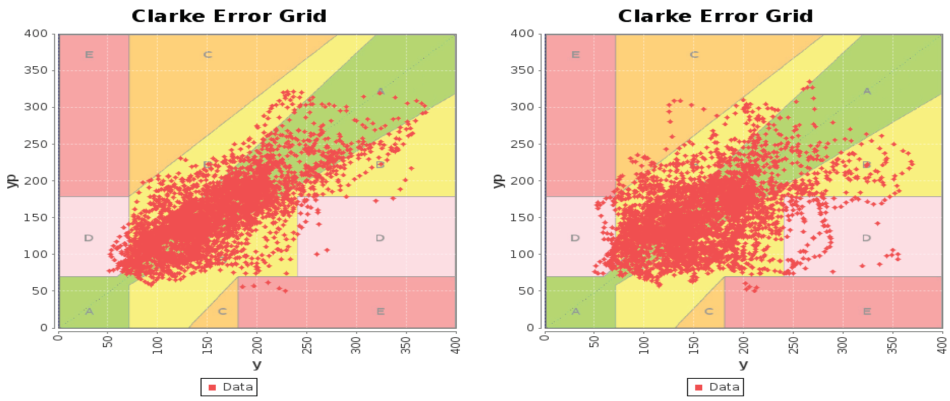


Fig. 1. Clarke Error Grid Analysis Results for 60 (left) and 120 (right) minutes for Patient 1

predictors were training and tested using real data of 10 patients from a Public Hospital of Spain. We have analyzed experimental results in terms of Root Mean Squared Error (RMSE) and Error Grid Analysis (EGA) for the eight in-silico patients. EGA is commonly used in Endocrinology to test the clinical significance of differences between measurements and real value of blood glucose [3] and uses a cartesian diagram to represent the values of the prediction versus the reference (actual) values. The EGA graph is divided into five zones (A to E), depending on the severity of the missprediction. The values included in zones C to E are potentially dangerous, since the measure or prediction is far from being acceptable and the indicated treatment will be different from the correct. Figure 1 represents the results for one of the patient for predictions of 60 and 120 minutes. Experimental results show that symbolic regression with GE combined with a preproccesing of the Data make prediction of glucose with few values (less than 3%) on the dangerous zones of the Clarke EGA chart. Results for other patients are quite similar in quality.

References

1. J Manuel Colmenar, Stephan M Winkler, Gabriel Kronberger, Esther Maqueda, Marta Botella, and J Ignacio Hidalgo. Predicting glycemia in diabetic patients by evolutionary computation and continuous glucose monitoring. In *Proceedings of the 2016 on Genetic and Evolutionary Computation Conference Companion*, pages 1393–1400. ACM, 2016.
2. J. Ignacio Hidalgo, J. Manuel Colmenar, José L. Risco-Martin, Alfredo Cuesta-Infante, Esther Maqueda, Marta Botella, and José Antonio Rubio. Modeling glycemia in humans by means of grammatical evolution. *Applied Soft Computing*, (20):40–53, 2014.
3. W. Clarke, D. Cox, L. Gonder-Frederick, W. Carter, and S. Pohl. Evaluating clinical accuracy of systems for self-monitoring of blood glucose. *Diabetes Care*, 10(5):622–628, 1987.

Fitness Landscape Analysis in the Optimization of Coefficients of Curve Parametrizations

Stephan M. Winkler[1] and J. Rafael Sendra[2]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, Hagenberg
stephan.winkler@fh-hagenberg.at

[2] Dpto. de Física y Matemáticas, Research Group ASYNACS
Universidad de Alcalá de Henares
rafael.sendra@uah.es

In this work we deal with the following problem in constructive algebraic geometry: Parametric representations of geometric objects, as curves or surfaces, may have unnecessarily huge integer coefficients. Our goal is to search for an alternative parametric representation of the same object with significantly smaller integer coefficients. We have developed and implemented an evolutionary algorithm that is able to find solutions to this problem in an efficient as well as robust way, and we published that algorithm in [1]; in this paper we analyze the fitness landscapes associated with this evolutionary algorithm.

More precisely, we are given a (proper) parametrization of a curve, expressed as

$$\mathcal{P}(t) = \left(\frac{p_1(t)}{q(t)}, \ldots, \frac{p_r(t)}{q(t)}\right) \tag{1}$$

with $p_i, q \in \mathbb{Z}[t]$ coprimes. Our goal is to find $a, b, c, d \in \mathbb{Z}$, with $ad - bc \neq 0$, such that we can substitute t by $(at+b)/(ct+d)$ and the height (i.e., the maximum coefficient in absolute value) of

$$\mathcal{P}\left(\frac{at+b}{ct+d}\right) \tag{2}$$

is minimal. In [1] we presented an evolutionary algorithm that is able to solve this problem. Roughly speaking, this algorithm works in two phases: First, partial solutions are identified and collected in the set Ω_e. Each element $\mathbf{o}$ in Ω_e is defined as $\mathbf{o} = (o_1, o_2) \in \mathbb{Z}^2$ with $\gcd(o_1, o_2) = 1$. Second, the best combinations of elements in Ω_e for composing the final complete solution of the given problem have to be found. Using $(\mathbf{o}_1, \mathbf{o}_2) \in \Omega_e \times \Omega_e$ with $\mathbf{o}_1 = (a, c)$, and $\mathbf{o}_2 = (b, d)$, the associated complete solution candidate is $S_{\mathbf{o}_1,\mathbf{o}_2} := (a, c, b, d)$. In order to measure the quality of a complete solution candidate $\mathbf{s} := S_{\mathbf{o}_1,\mathbf{o}_2}$ we use the notion of complete quality as the height of the resulting parametrization after substituting t by $(at+b)/(ct+d)$. This second phase of the algorithm is implemented as an evolutionary algorithm that finds the best combination of partial

The authors gratefully acknowledge financial support within the projects *MTM2014-54141-P* (Ministerio de Economía y Competitividad and European Regional Development Fund ERDF) and *HOPL* (Austrian Research Promotion Agency FFG, #843532).

solutions. We here work on ordered copies of Ω_e, denoted as Ω_e^{ord}. As we use an evolutionary process to find optimal combinations of partial solutions, the fitness function that evaluates these partial solutions is of essential importance.

In this work we analyze the effect of the use of various fitness functions for partial solutions. We can for example use the following fitness function:

$$\text{Quality}_{\text{p}}(\mathbf{o}, \mathcal{P}) = \gcd(P_1(\mathbf{o}), \ldots, P_r(\mathbf{o}), Q(\mathbf{o})), \quad (3)$$

where P_i, Q are the homogenizations of p_i, q, respectively. Figure 1 shows exemplary fitness landscapes of combinations of elements in Ω_e for a given problem where partial solution candidates are unordered (shown left) or ordered by means of their evaluation according to that function (shown right).

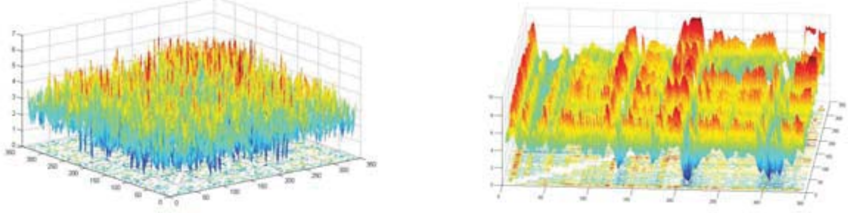


Fig. 1. Fitness landscape for combinations of elements of Ω_e for a parametrization $\mathcal{P}(t)$ defined in [1]. Each cell (x, y) represents the fitness of combination of $x \in \Omega_e$ (right $x \in \Omega_e^{\text{ord}}$) and $y \in \Omega_e$ (right $y \in \Omega_e^{\text{ord}}$).

For analyzing the characteristics of the fitness landscapes formed using fitness functions we use the metrics described in [2]. Concretely, we will use trajectory based metrics (random walks, adaptive and up-down walks, and neutral walks), use metrics describing the characteristics of the surface (e.g. the ruggedness), and estimate the hardness of the resulting problem by measuring how hard it becomes to solve the composed problem, i.e., how much effort has to be done in the second phase of the algorithm to find (nearly) optimal solutions.

Using these metrics and measures we characterize the fitness landscapes retrieved using different partial fitness functions for a series of benchmark problem with varying size and hardness. Those partial fitness functions that lead to better fitness functions will then be used instead of other ones that lead to suboptimal orderings of the partial solution candidates that make it difficult or impossible for the evolutionary algorithm to find optimal complete solutions.

References

1. Sendra, J.R., Winkler, S.M.: A heuristic and evolutionary algorithm to optimize the coefficients of curve parametrizations. Journal of Computational and Applied Mathematics **305** (2016) 18 – 35
2. Pitzer, E., Beham, A., Affenzeller, M.: Generic hardness estimation using fitness and parameter landscapes applied to robust taboo search and the quadratic assignment problem. In: Proceedings of GECCO 2012, ACM (2012) 393–400

Integrating Exploratory Landscape Analysis into Metaheuristic Algorithms

Andreas Beham[1,2], Erik Pitzer[1], Michael Affenzeller[1,2]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria
Softwarepark 11, 4232 Hagenberg

[2] Institute for Formal Models and Verification
Johannes Kepler University Linz
Altenberger Straße 69, 4040 Linz

andreas.beham@fh-ooe.at, erik.pitzer@fh-ooe.at
michael.affenzeller@fh-ooe.at

Motivation and Previous Work According to the No-Free-Lunch (NFL) theorem one heuristic may outperform all others only with respect to a certain subset of problems and instances [1]. To each problem instance there are associated fitness landscapes that can be used to characterize the instance through measuring certain properties. An often stated property of landscapes is its ruggedness [2, 3] with several measures linked to it [4]. In exploratory landscape analysis (ELA) [5] such measures are approximated involving sampling techniques such as random, adaptive, up/down, or neutral walks [2]. The downside of some existing techniques is that they must be performed independently of each other and require quite some time to compute. In an application it might not always be possible to obtain a thorough analysis on the landscape beforehand. When a solution needs to be given in short time, we would rather seek to gather landscape information within an algorithm run. In this work, we analyze how the performance of heuristics or operators, as they come to application during the optimization, may be used to characterize landscapes. By embedding this analysis in the optimization run, the metaheuristic will not only yield a good solution, but also report useful data on the observed landscape features, which has the potential to point the user at a more suitable method to apply next.

Method In this work we will focus on the well-known path-relinking (PR) [6] heuristic as a basis for obtaining landscape information. PR can be said to perform a kind of *directed walk* in the landscape, computing a best-improvement path between two known points. If the two points are randomly sampled and of average quality, the path most likely follows a U-shaped pattern as shown in Fig. 1 (assuming a minimization problem). We will describe several characteristics that can be computed from such results and which can be used to discriminate problem instances. An algorithm instance that uses path relinking could thus identify similarities to other problem instances while it is running, and potentially reconfigure its parameters.

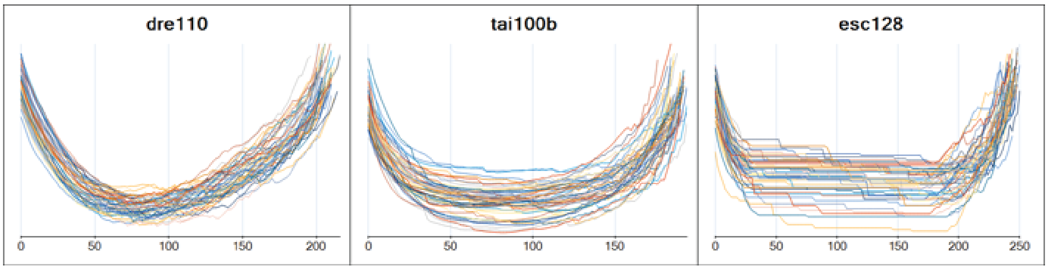


Fig. 1. 50 different directed walks between randomly sampled solutions on landscapes of different generators of the quadratic assignment problem.

Outlook We will describe several measures that can be obtained from directed walks and put these into relation with measures from existing sampling techniques in the context of problem similarity and algorithm selection. We will show how a performance observer can use previously recorded information in order to detect the problem instance while an algorithm instance is running to solve it. The study is performed for permutation-based combinatorial optimization problems.

Acknowledgments The work described in this paper was done within the COMET Project Heuristic Optimization in Production and Logistics (HOPL), #843532 funded by the Austrian Research Promotion Agency (FFG).

References

1. Wolpert, D.H., Macready, W.G.: No free lunch theorems for optimization. IEEE Transactions on Evolutionary Computation **1** (1997) 67–82
2. Pitzer, E., Affenzeller, M.: A Comprehensive Survey on Fitness Landscape Analysis. In: Recent Advances in Intelligent Engineering Systems. Springer Berlin Heidelberg, Berlin, Heidelberg (2012) 161–191
3. Richter, H., Engelbrecht, A.: Recent advances in the theory and application of fitness landscapes. Springer (2014)
4. Chicano, F., Luque, G., Alba, E.: Autocorrelation measures for the quadratic assignment problem. Applied Mathematics Letters **25** (2012) 698–705
5. Mersmann, O., Bischl, B., Trautmann, H., Preuss, M., Weihs, C., Rudolph, G.: Exploratory landscape analysis. In: Proceedings of the 13th Annual Conference on Genetic and Evolutionary Computation. GECCO '11, New York, NY, USA, ACM (2011) 829–836
6. Glover, F.: A template for scatter search and path relinking. Lecture notes in computer science **1363** (1998) 13–54

Sliding Window Symbolic Regression for Predictive Maintenance using Model Ensembles

Jan Zenisek[1,2], Michael Affenzeller[1,2], Josef Wolfartsberger[1], Mathias Silmbroth[1], Christoph Sievi[1], Aziz Huskic[1], Herbert Jodlbauer[1]

[1] Institute for Smart Production
University of Applied Sciences Upper Austria
Campus Hagenberg, Steyr, Wels

[2] Institute for Formal Models and Verification
Johannes Kepler University Linz
Altenberger Straße 69, 4040 Linz

jan.zenisek@fh-hagenberg.at

Motivation In this work we will present a method for the classification of system states in real-time by analyzing a continuous stream of data, which describes a system's behavior progressively. The motivation for such a method stems from the idea of Predictive Maintenance (PdM), which aims for sophisticated scheduling of maintenance, mostly for production plants in the industrial area. Instead of fixed maintenance intervals, service actions are planned based upon previous and current system states in order to predict and successively prevent outages which leads to less redundant maintenance procedures and less necessary overhauls. As in [1], we assume that identified gradual shifts or more abrupt changes in historic sensor time series, which are not directly derivable from input variables and therefore caused by hidden impacts, might link to defective system behavior and therefore the need for maintenance. One major challenge regarding the observation of a continuous data stream, representing a system's in and output is the volume of time series data generated [2]. Furthermore, the necessity for maintenance can be raised by an previously unknown number of different kinds of misconducts which might occur.

Method In order to deal with the challenges stated above, we propose the employment of the Genetic Programming (GP) based Sliding Window Symbolic Regression (SWSR) approach [1], which enables to learn prediction models based on stream data partition-wise by moving a window over the data. Moreover, SWSR provides indicators for the detection of so-called regime changes and shifts in system dynamics. However, for the eventual classification of system states this work proposes to shift the task of model building into an offline phase, during which several data streams, representing various possible system behaviors, are analyzed. The outcome of this phase are models, which consequently

The work described in this paper was done within the project "Smart Factory Lab" which is funded by the European Fund for regional development (EFRE) as part of the program "Investing in Growth and Jobs 2014-2020".

can be interpreted and classified as different system states (e.g. class 1: neutral, class 2: potentially defective, class 3: total outage, etc.) by domain experts. As an additional or alternative system state classification method, we introduced an automatic state detection strategy which we will amplify in the full paper. Subsequently, the classified models are pooled to an ensemble, which is capable of making more robust and trustworthy predictions especially in case of volatile environments [3, 4].

On top of the preparatory ensemble construction the actual online classification method of data streams has been enabled. Therefore, we consider a stream of previously unseen data, for which the following ensemble voting process aims to determine the correct class:

1. Read data from stream and pass the system's input parameters to each of the learned regression models in the ensemble
2. Compare the predicted model outputs with the factual system output, read from the stream; If the calculated squared *Pearson* correlation coefficient R^2 is above a certain user-defined threshold, the model votes for the class it has previously interpreted to
3. The class with the majority of votes is determined as winning, if a user-defined threshold of clearness [4] is reached

The technique presented in this paper has been implemented using the open-source optimization environment HeuristicLab[1]. In reference to an exemplary real-world PdM scenario our approach has shown promising results when tested with an adapted variant of the synthetic data set introduced in [1], which simulates a time-dependent process with multiple input variables, one output variable and several hidden state changes, causing shifts and changes in data time series. In the full paper we elaborate on the details of the training and ensemble voting procedure as well as on our findings on the test data set.

References

1. Winkler, S.M., Affenzeller, M., Kronberger, G., Kommenda, M., Burlacu, B., Wagner, S.: Sliding window symbolic regression for detecting changes of system dynamics. In: Genetic Programming Theory and Practice XII. Springer (2015) 91–107
2. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of things (iot): A vision, architectural elements, and future directions. Future Generation Computer Systems **29** (2013) 1645–1660
3. Winkler, S., Schaller, S., Dorfer, V., Affenzeller, M., Petz, G., Karpowicz, M.: Data-based prediction of sentiments using heterogeneous model ensembles. Soft Computing **19** (2015) 3401–3412
4. Affenzeller, M., Winkler, S.M., Stekel, H., Forstenlechner, S., Wagner, S.: Improving the accuracy of cancer prediction by ensemble confidence evaluation. In: International Conference on Computer Aided Systems Theory, Springer (2013) 316–323

[1] http://dev.heuristiclab.com

A performance assessment of network address shuffling in IoT systems

Georg Merzdovnik[1,2], Aljosha Judmayer[1], Artemios G. Voyiatzis[1,2], and Edgar Weippl[2,1]

[1] SBA Research, Vienna, Austria
{gmerzdovnik,ajudmayer,avoyiatzis,eweippl}@sba-research.org
[2] TU Wien, Vienna, Austria

Networked embedded systems of different forms and shapes are the building blocks for the Internet of Things (IoT). The security of these systems is of paramount importance for the function of the Internet already. Despite the constraints in memory, processing, and power, the network connectivity is often more than ample. IoT devices often have network access interfaces of 100 Mbps or even 1 Gbps. This combined with the exploding number of Internet-connected devices gives rise to new forms of attacks.

The two most severe distributed denial of service (DDoS) attacks ever faced on the Internet, with an aggregate traffic volume of more than 1.1 Tbps occurred in 2016. These attacks became feasible due to the availability of numerous vulnerable and compromised IoT systems, including devices such as digital video recorders (DVRs), IP cameras, and smart thermostats.

The resource constraints of these embedded systems make it difficult to integrate network security mechanisms that are commonplace in enterprise IT environments. Furthermore, the former are often part of smart homes and smart environments. In these settings, the consumers opt for a set-and-forget approach. Software updates and upgrades are in many cases impossible to realize.

In this modus operandi, it is crucial to engineer defenses that are *preventive* in nature. Most of the IoT systems are, from a network perspective, "*sitting ducks*", i.e., they are easily accessible from the network and passively receive all kind of attacks aiming to compromise them.

Moving-target defense (MTD) is an approach to improve the standing of defending information systems in general by breaking this attacker-defender asymmetry [3]. The key assumption for MTD is that the attackers will first perform a reconnaissance to identify possible targets. Then, at a next phase, they launch their (targeted) attack. Under this assumption, MTD dictates to mobilize the available resources, so that the attackers hit wrong or non-existent targets and thus, succeed in defending the systems; collect evidence of their behavior; and provide enough time to deploy network-wide defenses (e.g., honeypots) for further studying their practices and delaying further attacks [4].

While host- and application-level MTDs are hard to realize in embedded systems, network-level ones (e.g., time-varying topology) are considered feasible [2]. IPv6 and IPv4 network address shuffling, i.e., periodically changing the network addresses of the devices in a coordinated way, is an example network-level MTD [1].

In this paper, we augment existing literature by exploring the capability of modern IoT systems to handle network address shuffling. More specifically, we study the performance overhead and the impact of periodically changing network addresses and ports in Linux-based IoT systems (namely, Raspberry Pi and Carambola2) under different probing and network scanning activity scenarios.

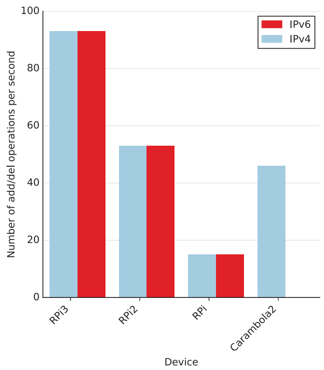


Fig. 1. Address change operations per second and device

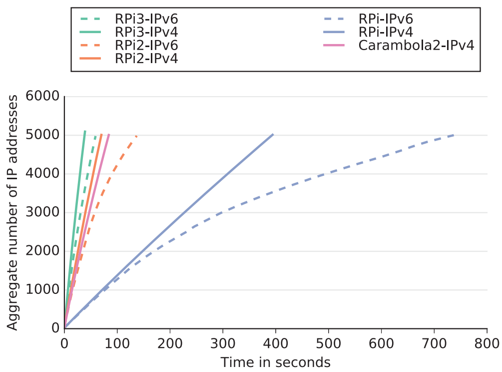


Fig. 2. Total number of IP addresses

Our findings indicate that network address shuffling is feasible in IoT environments. However, special care must be taken when implementing such techniques. The number of possible IP address changes per second varies significantly per device, as depicted in Figure 1. The simultaneous use of multiple IP addresses has an impact in the performance, especially in the case of IPv6, as depicted in Figure 2: the more addresses already in use, the more time to add new ones. Interestingly enough, Carambola2, running OpenWRT with a clock rate of 400 MHz clearly outperforms the *stronger* Raspberry Pi B+ clocked at 700 MHz, reaching the figures of Raspberry Pi 2, which is clocked at 900 MHz and has four cores.

References

1. Cai, G., Wang, B., Wang, X., Yuan, Y., Li, S.: An introduction to network address shuffling. In: 18th International Conference on Advanced Communication Technology (ICACT). pp. 185–190. IEEE (2016)
2. Casola, V., De Benedictis, A., Albanese, M.: A moving target defense approach for protecting resource-constrained distributed devices. In: 14th International Conference on Information Reuse and Integration (IRI). pp. 22–29. IEEE (2013)
3. Jajodia, S., Ghosh, A.K., Swarup, V., Wang, C., Wang, X.S.: Moving target defense: creating asymmetric uncertainty for cyber threats, vol. 54. Springer Science & Business Media (2011)
4. Zhuang, R., DeLoach, S.A., Ou, X.: Towards a theory of moving target defense. In: Proceedings of the First ACM Workshop on Moving Target Defense. pp. 31–40. ACM (2014)

Mobile Wrist Vein Authentication Using SIFT Features

Pol Fernández and Rainhard Dieter Findling

Department of Mobile Computing, University of Applied Sciences Upper Austria,
Softwarepark 11, 4232 Hagenberg, Austria,
pol.fernandez@students.fh-hagenberg.at,
rainhard.findling@fh-hagenberg.at,
http://www.fh-ooe.at/en/

Abstract. Biometrics have become important for authentication on modern mobile devices. Thereby, different biometrics are differently hard to observe by attackers: for example, veins used in vein pattern authentication remain hidden when not using specialized hardware. In this paper we propose a low cost mobile vein authentication system based on SIFT features. We implement our approach as vein recording and authentication prototype, evaluate it using a self recorded vein database, and compare results to other vein recognition approaches applied on the same data.

Keywords: mobile authentication, NIR, SIFT features, wrist veins

1 Introduction

Modern mobile devices have access to, store, and process much private information, such as with messaging (email, SMS), contacts, access to private networks (VPN, WiFi), or even mobile banking. Thus, most mobile devices provide local access protection mechanisms, such as PIN, password, or fingerprint authentication. The used authentication information could thereby be observed and used in replay attacks by attackers. However, some biometrics are more difficult to observe by attackers, as they remain hidden without special sensing technology.

Vein pattern authentication has gained popularity for being contactless, while users' veins largely remain hidden within the visible spectrum of light. To discover vein patterns, near infrared (NIR) light and cameras with an optical NIR bandpass filter are usually used [2, 6]. As NIR light is not visible to neither humans nor regular cameras, capturing vein patterns is more difficult for attackers than e.g. observing face information used for face authentication. Most vein capturing approaches use finger, hand dorsal, palm, or wrist veins [1, 7]. For mobile users, wrist veins have the advantage of being easily accessible: in the future, wrist vein authentication could be done e.g. by smartwatches, which would not require any effort and/or changes in behavior for the user. Existing vein recognition approaches use e.g. fast spatial or 2D correlation [5, 3], or spectral minutiae [1]. In this paper we present another approach: we combine low cost mobile wrist vein recording with SIFT features for vein authentication.

2 Mobile Wrist Vein Authentication With SIFT Features

The aim of this paper is to advance mobile vein authentication by combining low cost mobile vein recording with SIFT features for authentication [4]. We record vein images from a NIR sensitive camera with NIR LEDs, then apply image filtering and segmentation with local thresholding to obtain vein pattern images. From obtained vein patterns we derive SIFT descriptors as reliable vein pattern keypoints. For two given vein patterns, those can be compared to decide if both patterns have been originated by the same person, which thereby enables vein authentication. We evaluate our approach using a self recorded wrist vein image database and compare it to other approaches, such as vein pattern image correlation.

3 Current Results

We have implemented a mobile vein pattern recording and authentication prototype using an external NIR sensitive USB camera with 24 NIR LEDs. Currently, the thereby recorded mobile wrist vein database contains 10 individuals, which we plan on extending to more than 30 individuals. First experimental results show a reliable recognition of individuals with well visible veins. From extracted SIFT features of two vein patters, we currently use the mean of the closest features across both patterns a basis for the authentication decision. Our approach thereby seems to only require 4 images per individual to correctly distinguish between vein pattern images originated by the same person and those originated by different people. Applying vein pattern 2D image correlation on the same dataset seem to lead to slightly worse results, thereby would be in favor of using SIFT features.

We plan on further improving and fine tuning our vein authentication, as well as deepening the underlying evaluation to obtain a more broad and representative basis for conclusions.

References

1. L. Z. Y.-Z. C. Cheng-Bo Yu, Hua-Feng Qin. Finger-vein image recognition combining modified hausdorff distance with minutiae feature matching. 2009.
2. S. Juric and B. Zalik. An innovative approach to near-infrared spectroscopy using a standard mobile device and its clinical application in the real-time visualization of peripheral veins. *BMC Medical Informatics and Decision Making*, 14(1):100, 2014.
3. R. Kabaciński and M. Kowalski. Vein pattern database and benchmark results. *Electronics Letters*, 47(20):1127–1128, 2011.
4. B. D. Pierre-Olivier Ladoux, Christophe Rosenberger. Palm vein verification system based on sift matching. 2009.
5. M. Shahin, A. Badawi, and M. Kamel. Biometric authentication using fast correlation of near infrared hand vein patterns. *International journal of Biomedical Sciences*, 2(3):141–148, 2007.
6. J. Suarez Pascual, J. Uriarte-Antonio, R. Sanchez-Reillo, and M. Lorenz. Capturing hand or wrist vein images for biometric authentication using low-cost devices. In *Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP) 2010*, pages 318–322, Oct. 2010.
7. L. Wang, G. Leedham, and S.-Y. Cho. Infrared imaging of hand vein patterns for biometric purposes. *IET Computer Vision*, 1:113–122(9), Dec. 2007.

One Degree of Freedom Copter

Peter Ťapák, Mikuláš Huba

Institute of Automotive Mechatronics
Faculty of Electrical Engineering and Information Technology
Slovak University of Technology in Bratislava
Ilkovičova 3, 812 19 Bratislava, Slovakia
{peter.tapak,mikulas.huba}@stuba.sk

Abstract. The paper deals with the altitude control of a laboratory model of an unmanned aerial vehicle. Ultra local models are used for the system approximation. Several kinds of filters are used in the closed loop for measurement noise reduction and control signal oscillation mitigation. Several variations of PD and PID controllers are used to control the altitude of the model. The results of the real experiments are evaluated by integral criteria to analyze power efficiency.

Keywords: UAV, altitude control, ultra local model

1 Introduction

The unmanned aerial vehicles (UAV) have been very popular for several years already. It is very common practice to use PD controllers for attitude stabilization and altitude control. In this paper, the control of very simplified laboratory model of an UAV consisting of a platform with only one propeller is presented. The plant construction was inspired by papers [3],[1]. The altitude of the platform is measured by an ultrasonic sensor. Since the most popular UAVs, multicopters, do spend a lot of time in hover mode while performing their tasks, the altitude control of this vehicle ranks among the tasks requiring special attention. The altitude control algorithms presented in this paper use ultra local models (see e.g.[2]) of the plant for tuning. The least squares method was employed in identification process. The controller performance has been evaluated taking into account the total variance of control signal, in other words the sum of all control signal changes which gives the reader nice overview on power consumption. The finite impulse response filter, binomial filter of second, third and fourth order have been applied to the process variable measurement to reduce measurement noise and enhance power efficiency.

2 Plant parts

The parts which the model consists of were chosen to be the same as can be used on a real multicopter. However, the cheap ones were used, because there was no need to lift a lot of payload. The BLDC motor A2212 was used for the copter propulsion. The motor came with the electronic speed controller (ESC) and a pair of propellers. To measure the platform altitude the SR04 ultrasonic sensor was bought. When seeing the components above, it is not a surprise that the Arduino UNO R3 microcontroller is used to control the monocopter.

3 Real time control and measurement

The sampling time was chosen to be 20ms as it is the sampling time of the motor's ESC and it is sufficient to measure the platform altitude by the ultra sonic sensor up to 1m. However this has brought difficulties in measurement filtering especially when applying filters of higher orders with small time constants.

4 Conclusion

The carried out experiments show that the developed identification method yields results applicable in control of a broad range of UAVs. The parameters of ultra local models were easy to find and yielded sufficient approximation for the appropriate control loop design.

Acknowledgment

This work has been partially supported by the grants APVV-0343-12 Computer aided robust nonlinear control design and VEGA 1/0937/14 Advanced methods for nonlinear modeling and control of mechatronic systems.

References

1. Bermdez-Ortega, J., Besada-Portas, E., Lpez-Orozco, J., Bonache-Seco, J., de la Cruz, J.: Remote web-based control laboratory for mobile devices based on ejss, raspberry pi and node.js**this work has been supported by the spanish national research project dpi2013-46665-c2-1-r. IFAC-PapersOnLine 48(29), 158 – 163 (2015), `http://www.sciencedirect.com/science/article/pii/S240589631502488X`
2. Fliess, M., Join, C.: Model-free control. International Journal of Control 86(12), 2228–2252 (2013), cited By 19
3. Sanchez, D.: Vertical Rotor for the Implementation of Control Laws . In: 9th IFAC Symposium Advances in Control Education. Nizni Novgorod, Russia (2012)

Prediction of Coverage of Expensive Concurrency Metrics Using Cheaper Metrics

Bohuslav Křena, Hana Pluháčková, Shmuel Ur, and Tomáš Vojnar

IT4Innovations Centre of Excellence, FIT, Brno University of Technology, Czech Republic
{krena, ipluhackova, vojnar}@fit.vutbr.cz
shmuel.ur@gmail.com

With the current massive use of multicore processors, concurrent programming has become widespread. Such programming is, however, far more challenging since apart from errors that one can cause in sequential code, various synchronization-related errors specific for concurrent code can appear too. What is worse, such bugs are common but difficult to find since they often manifest under some very specific conditions only. Therefore, advanced approaches for finding such errors are highly needed.

A traditional, yet still dominating approach to finding errors is *testing*. However, for testing to be effective even in the context of concurrent code, special care must be taken to cope well with the nondeterminism of thread scheduling. First, to steer the testing process, various *coverage metrics* are often used. In the case of testing of concurrent code, traditional coverage metrics (such as statement coverage) are not sufficient since they do not reflect how well the concurrent behaviour has been exercised. Instead, one needs to use specialised metrics, such as coverage of concurrently executing instructions, synchronisation coverage, or coverage of internal states of dynamic analysers while chasing for various concurrency-related bugs [4].

In order to maximize coverage under a suitable concurrency coverage metric, one has to cope with the nondeterminism of thread scheduling. For that, simple repetitive execution of the same tests in the same environment does not help much [3]. Indeed, despite the scheduling is nondeterministic, some schedules may occur only rarely for the given configuration. One way to resolve this problem is to use the approach of *noise injection* [2, 3] which influences the thread scheduling by injecting different kinds of noise (e.g., context switches or delays) into the execution of a concurrent program. However, there are many heuristics for *generating noise* and for deciding *where to place it*, which are, moreover, heavily parametrised. Finding the right values of the parameters of noise generation together with the right test cases and suitable values of their possible parameters forms the so called *test and noise configuration setting* problem (TNCS problem).

If the TNCS problem is not solved properly, the use of noise can even decrease the obtained coverage [3]. However, solving the TNCS problem is not an easy task either. Sometimes, its solution is not even attempted, and purely random noise generation is used. Alternatively, one can use genetic algorithms or data mining [3, 1]. These approaches can outperform the purely random approach, but finding suitable test and noise settings can be quite costly. The aim of this paper is to make the cost of finding a suitable test and noise setting lower.

The approach which we propose is based on the facts that (1) maximizing coverage under different metrics may have different *costs*, and (2) there may exist *correlations* between test and noise settings suitable for maximizing coverage under different metrics. Moreover, these correlations may exist even between metrics for which the process of maximizing coverage is expensive but which are highly informative for steering the testing process, and metrics for which the process of maximizing coverage is cheaper but which are less efficient when used alone for steering the testing process.

We suggest to *optimize the testing process* in the following way. Given some expensive but informative metrics, one may find suitable values of test and noise parameters for maximizing coverage under these metrics by experimenting with coverage under some cheap metric (or a combination of such metrics) and then use this setting for testing with the expensive metrics. We show on a set of experiments that this approach can indeed increase the efficiency of noise-based testing.

Our contribution is thus threefold: (1) An experimental assessment of the costs of maximizing coverage under different concurrency metrics. (2) The observation that test and noise settings suitable for testing under cheap and more expensive metrics may correlate and its experimental confirmation. (3) The idea of how to exploit such correlations for more efficient noise-based testing, together with its experimental evaluation.

We have performed our experiments on a set of multi-threaded benchmark programs whose size ranges from 0.3 kLOC to 12.7 kLOC. The experiments include the following steps. First, we evaluate the cost of maximizing the coverage under different metrics and classify them as cheap or expensive. Then, we derive a predictive model to predict settings suitable for maximizing combined coverage under three expensive metrics based on two cheap ones (such combinations are a natural answer to the fact that no coverage is the best of all). Finally, we show that this approach can indeed improve the efficiency of the noise-based testing process.

To create the above mentioned predictive model, we use the common lasso algorithm. The model has (roughly) a 0.8 correlation rate with a fitness function summarizing coverage under the three expensive metrics (each normalized wrt the maximum coverage obtained under the respective metric). We show that, on average, finding a suitable TNCS solution this way speeds up the testing process by about one third and makes the results twice more stable compared with random noise-based testing. Moreover, we achieve slightly better results in coverage of the expensive metrics too. The methodology used in this paper has many applications, not only in the concurrent domain.

Acknowledgement. Supported by the Czech Science Foundation (project 17-12465S) and the IT4IXS: IT4Innovations Excellence in Science project (project LQ1602).

References

1. R. Avros, V. Hrubá, B. Křena, Z. Letko, H. Pluháčková, S. Ur, T. Vojnar, and Z. Volkovich. Boosted Decision Trees for Behaviour Mining of Concurrent Programs. In *Proc. of MEMICS'14*, pages 15–27. NOVPRESS (2014).
2. O. Edelstein, E. Farchi, E. Goldin, Y. Nir, G. Ratsaby, and S. Ur. Framework for Testing Multi-threaded Java Programs. *Concurrency and Computation: Practice and Experience*, 15(3-5):485–499. Wiley (2003).
3. J. Fiedor, V. Hrubá, B. Křena, Z. Letko, S. Ur, and T. Vojnar. Advances in Noise-based Testing of Concurrent Software. In Software Testing, Verification and Reliability, 25(3):272–309. Elsevier (2015).
4. B. Křena, Z. Letko, and T. Vojnar. Coverage Metrics for Saturation-based and Search-based Testing of Concurrent Software. In *Proc. of RV'11*, volume 7186 of LNCS, pages 177–192. Springer-Velrlag (2012).

Smaller Invariants for Proving Coverability of Parallel Programs*

Lukáš Holík, and Lenka Turoňová

Faculty of Information Technology, Brno University of Technology
{holik,turonova}@fit.vutbr.cz

In this work, we explore a possibility of improving existing methods for verification of parallel programs. We particularly concentrate on safety properties of *well-structured transition systems* (WSTS), a general class of systems which include for instance Petri nets, lossy channel systems, or various broadcast and mutual exclusion protocols. Our work has relevance mainly to recent methods originating from the backward reachability analysis [1] such as [5, 4, 2], that are based on finding an *inductive invariant* of the system. A safe inductive invariant is a set of configurations of the system with the three following properties: (a) contains its initial configurations; (b) does not intersect with the undesired configurations; and (c) is closed under the transition relation. The properties together are an inductive proof of safety of the system.

The algorithms of [5, 4, 2] all learn an invariant of the same form: as the complement of an upward-closed set representing a set of undesirable configurations. They build-up the invariant by iterative steps, adding parts to the current invariant approximation in order to satisfy inductiveness. To accelerate the process, they overapproximate the so far constructed part of the invariant using abstraction. The abstraction is regulated by variations of *counterexample-guided refinement* (CEGAR). The basic variant of CEGAR runs the program within the abstract domain and in the case of reaching an error configuration, the error path, so called *counterexample*, is analyzed. If there is a corresponding real run in a system then they found an error. Otherwise, the error path is spurious and we have to find a way how to refine the abstraction to prevent it from generating the error path again. The abstraction refinement here corresponds to a refinement of the current overapproximation of the so far constructed part of the invariant.

We conjecture that heuristics for finding more succinct invariants would help to improve the overall performance of the discussed methods [5, 4, 2], for the following reasons: the invariant approximations are the most costly data that the methods work with, and so the price of the analysis depends directly on the size of the invariant representation. Moreover, the more succinct invariants can be usually found by less invariant building steps. The methods [5, 4] attempt to guess succinct invariants in a certain way. However, the search for the components of an invariant and the choice of overapproximation are to a large degree greedy and uninformed. Therefore, the inferred invariants are far from optimal and contain much more information that is needed to prove inductiveness.

* This work was supported by the Czech Science Foundation project 16-24707Y.

To show that there is a possibility to find more succinct invariants we have experimented with the method presented in the article [2](GBR). It uses backward analysis to explore the state space of the counterexample abstract runs. It iterates operation *pre* starting from the set of concrete error configurations. It uses uninformed greedy breadth-first search strategy which leads to unnecessarily verbose invariants.

We have modified GBR in such way that it analyzes spurious counterexamples in a rather depth-first manner. In order to decide which parts should be added to the invariant and how to overapproximate them, we analyze complete abstract paths leading to error configurations, so called *minimal counterexample runs*. We then hope to determine a minimal (most succinct and the most general) reason that the run is spurious. The minimal reason has a potential to be a part of the minimal inductive invariant since 1) it is necessary to refute the examined spurious counterexample run and 2) it is a “minimal” such “reason” (we note that the minimal reasons are in the essence inductive interpolants). In contrast to the breadth-first greedy strategy, many useless candidates for parts of the invariant and unsafe overapproximations can be this way avoided.

We so far propose only a naive method for the analysis of minimal runs. It is sufficient to generate more succinct invariants, but it is not yet optimized for overall efficiency: From each minimal run, we randomly select a subset of components of transition preconditions appearing in it and use it to extend the invariant.

We have implemented this method in a prototype tool in Python. We have implemented also the original algorithm GRB and compared the size of generated invariants on several verification tasks from the benchmark of MIST2 [3] (safety properties of parameterized programs communicating via shared variables and mutexes). Since our method chooses invariant candidates randomly, we used the most succinct invariant generated in a large number of executions. This was much more time consuming than running GBR. We have however succeeded in generating significantly more succinct invariants than GRB. It confirms that with an efficient analysis of the minimal counterexample runs, our approach has a potential to be more efficient than GBR. Our future research will therefore focus on efficient analysis of minimal counterexample runs.

References

1. Parosh Aziz Abdulla. Well (and better) quasi-ordered transition systems. *Bulletin of Symbolic Logic*, (4), 2010.
2. Pierre Ganty, Jean-François Raskin, and Laurent Van Begin. A complete abstract interpretation framework for coverability properties of WSTS. In *VMCAI'06*, volume 3855 of *LNCS*, pages 49–64. Springer, 2006.
3. Alexander Kaiser, Daniel Kroening, and Thomas Wahl. Bfc - a widening approach to multi-threaded program verification. http://www.cprover.org/bfc/.
4. Alexander Kaiser, Daniel Kroening, and Thomas Wahl. Efficient coverability analysis by proof minimization. In *CONCUR'12*, LNCS 7454. Springer, 2012.
5. Johannes Kloos, Rupak Majumdar, Filip Niksic, and Ruzica Piskac. Incremental, inductive coverability. In *CAV'13*, LNCS 8044. Springer, 2013.

Simplifying computations of singular configurations using features of manipulators' models

Ignacy Duleba⋆ and Iwona Karcz-Duleba

Wroclaw University of Science and Technology,
Faculty of Electronics, Janiszewski St. 11/17, 50-372 Wroclaw, Poland
{ignacy.duleba,iwona.duleba}@pwr.edu.pl

1 Introduction

A key task in robotics is to determine singular configurations of a manipulator (at those configurations the Newton algorithm of inverse kinematics [5], is ill-conditioned). It appears that some characteristics of robots (e.g. singularities) do not depend on the first coordinate of the configuration vector. This useful observation is not pointed out in textbooks [3–5] although Kircansky [2], searching for isotropic configurations of a planar pendulum, noticed that Jacobian matrices are particularly simple at some coordinate frames. To popularize this fact, we will show its theoretical background and original practical implications significantly simplifying computations of singular configurations.

Forward kinematics is a mapping

$$\mathbb{Q} \ni \boldsymbol{q} \rightarrow \boldsymbol{x} = \boldsymbol{K}(\boldsymbol{q}) = \boldsymbol{A}_0^n(q) = \begin{bmatrix} \boldsymbol{R}_0^n & \boldsymbol{T}_0^n \\ \boldsymbol{0}_{3,1} & 1 \end{bmatrix} = \prod_{i=1}^{n} \boldsymbol{A}_{i-1}^i(q_i) \in \mathbb{X} \subset \mathbb{SE}(3), \tag{1}$$

where $\mathbb{Q} \ni \boldsymbol{q}$ is a configuration space, $\mathbb{X}$ is a taskspace being a subspace of the special Euclidean group $\mathbb{SE}(3) \ni \boldsymbol{x}, \boldsymbol{0}_{3,1}$ is a (3×1) matrix of zeroes, $\boldsymbol{A}_{i-1}^i \in \mathbb{SE}(3)$ is a transformation between the $(i-1)st$ and the ith coordinate frames (0-th frame is the base (global) one, the n-th frame is fixed at the end-effector).

At singular configurations the Jacobian matrix $\boldsymbol{J}(\boldsymbol{q}) = \partial \boldsymbol{K}(\boldsymbol{q})/\partial \boldsymbol{q}$. looses it's maximal possible rank. In this report, based on properties of derive operators [1] and some facts from the theory of matrices, three facts were put forward, proved and illustrated:

Fact 1: The Jacobian matrix does not depend on q_1 coordinate at any frame $1, \ldots, n$, following the frame of motion of the first joint.

Fact 2: Singular configurations do not depend on q_1 coordinate.

Fact 3: While computing singularities, any value (denoted as $*$) can be assigned to the coordinate q_1

$$\boldsymbol{J}(\boldsymbol{q}) = \boldsymbol{J}((*, q_2, \ldots, q_n)). \tag{2}$$

The selected value of q_1 should simplify computations of the Jacobian and singularities as well. Notice that computations are performed in the global frame (excluded in Fact 1). The original Fact 3 is very useful and practical one.

⋆ This work has been supported by WUST within statutory grant No. 0401/0209/16.

2 Illustrating examples

Exemplary calculations were performed on models of $n = 2, 3$ dofs planar pendula with positional kinematics $(x, y) = (a_1c_1 + a_2c_{12}, a_1s_1 + a_2s_{12})$, $\boldsymbol{q} = (q_1, q_2)$, a_i - lengths of links $c_{12} = \cos(q_1 + q_2)$ Jacobians in the global frame $\boldsymbol{J}^0$ and in the 2nd frame $\boldsymbol{J}^2$ follows

$$\boldsymbol{J}^0 = \begin{bmatrix} -(a_1s_1 + a_2s_{12}) & -a_2s_{12} \\ a_1c_1 + a_2c_{12} & a_2c_{12} \end{bmatrix}, \quad \boldsymbol{J}^2 = \begin{bmatrix} a_1s_2 & 0 \\ (a_1c_2 + a_2) & a_2 \end{bmatrix}, \tag{3}$$

$\boldsymbol{J}^2$ does not dependent on q_1 and Fact 1 is confirmed. To show simplifications in computing singularities Fact 3 is applied to $\boldsymbol{J}^0$ setting $q_1 = 0$.

$$\mathrm{rank}(J(\boldsymbol{q}|q_1 = 0)) = \mathrm{rank} \begin{bmatrix} -a_2s_2 & -a_2s_2 \\ a_1 + a_2c_2 & a_2c_2 \end{bmatrix} = \mathrm{rank} \begin{bmatrix} -a_2s_2 & 0 \\ a_1 + a_2c_2 & -a_1 \end{bmatrix}. \tag{4}$$

From (4), it is easy to get the condition $a_1a_2s_2 = 0$ to determine singular configurations. They are met for $q_2 = k\pi/2$, $k \in Z$ and any value of q_1.

3 Conclusions

In this paper a method to simply computations of singular configurations of redundant and nonredundant manipulators was presented. Possible practical applications are based on speeding-up on-line computations of the characteristics and can be exploited either within a computer software or by lecturers of robotics at classes. The reasoning presented in this paper is heavily based on a geometric structure of $\mathbb{SE}(3)$, therefore it can not be applied to other concepts of kinematics (like endogeneous kinematics of nonholonomic robots [6]). The method can be also applied to simplify computations of manipulators' dynamics.

References

1. Brady, M., Hollerbach, J.M., Johnson, T.L., Lozano-Perez, T., Mason, M.T. (ed.): Robot motion. Planning and Control. MIT Press series in artificial intelligence, (1982)
2. Kircanski, M.: Robotic Isotropy and Optimal Robot Design of Planar Manipulators, In: Proc. IEEE Int. Conf. on Robotics and Automation, Vol. 2, pp. 1100-1105, (1998)
3. McKerrow, P.J.: Introduction to Robotics, Addison-Wesley Publ., Electronic Systems Engineering Series, (1991)
4. Murray, R.M., Li, Z. , Sastry, S.: A Mathematical Introduction to Robotic Manipulation, CRC Press, (1994)
5. Spong, M., Vidyasagar M.: Robot Dynamics And Control, John Wiley & Sons, (1989)
6. Tchon, K., Jakubiak, J.: Endogenous configuration space approach to mobile manipulators: a derivation and performance assessement of Jacobian inverse kinematics algorithms, Int. Journal of Control, 26(14), 1387-1419, (2003)

A Study of Designing Process of Sightseeing Support System using Bluetooth Low Energy Beacon

Atsushi Ito[1], Yuko Hiramatsu[2] Hiroyuki Hatano[1], Mie Sato[1], Akira Sasaki[3], Fumihiro Sato[2], and Yu Watanabe[1]

[1] Information System Science Department Graduate School of Engineering, Utsunomiya University, 7-1-2 Yoto, Utsunomiya, Tochigi, 321-8505, Japan,
{at.ito, hatano, mie, yu}@is.utsunomiya-u.ac.jp
[2] Faculty of Economics, Chuo University,
742-1Higashinakano, Hachioji, Tokyo 192-039, Japan,
{susana_y, fsato}@tamacc.chuo-u.ac.jp
[3] GClue Inc.,
134-3 Ikkimachi, Oaza Tsuruga, Aza Kamiiawase, Aizu-wakamatsu, Fukushima 965-8580, Japan,
akira@gclue.jp

Information and communication technology (ICT) is widely used for travel and tourists get not only maps but also enough information of shops, accommodations, museums, events etc. A large amount of information is not always appealing to tourists. While the provision of information may lessen the anxiety experienced by tourists, the promise of the unexpected is one of the things that make travel attractive. Since 2014, we have been developing a new sightseeing support application for Nikko, a world cultural heritage site in Japan, using Bluetooth Low Energy (BLE) [1] beacons that not only provides a guide to a specific location but also introduces the traditional customs and history of the area to visitors [2] . This is one of the research themes of SCOPE [3] funded by the Ministry of Internal Affairs and Communications of Japan.

In this presentation, we mainly discuss on the development process of our sightseeing support system and result of experiment. We designed the development process that is suitable for a service that uses devices embedded in environment. One of the key parts of this system is “beacon”. The balance between devices (beacon) and software (smartphone application) is very important. We define the design process described in Figure 1.

We firstly analyzed requirements (STEP1). Then defined service model (STEP2). After that step, we defined environments such as devices in the environment and how the devices and smartphones should be connected to networks. Then we defined system architecture. After this point, in the middle of Figure 1, there are two paths. One is design of devices and another is that of software. We developed them in parallel. This point is a peculiarity of this model.

In the path of develop devices (STEP5-1 to 5-5), we firstly designed concept of devices based on the requirements in STEP1. Next, we defined requirements of devices and environment where the devices were used. After that, we selected parts to meet requirements and developed the devices.

In the path of develop software (STEP6-1 to 6-5), we firstly designed concept of software from the requirements in STEP1.

Then we defined requirements for the software. After this step, we collected contents and data that could satisfy users of this system. Then we designed software and developed it. After developed both devices and software, we firstly performed integration test in the laboratories (STEP7).

Next, we installed devices in the real environment and performed system test by students of our universities and visitors of Nikko (STEP 8). After finishing the system test, we received test by application market operator. Then we registered our software in the application market and opened it to the public (STEP9).

In the remaining part of this presentation, we will mention the result of trials in Nikko. The result demonstrated the effectiveness of the BLE beacon for sightseeing on foot. The application made tourists notice new points on the route. Owners of shops en route to the main shrine cooperated by providing information regarding their goods and information on local traditions.

We expect that our system could enhance the tourist experience of a traditional cultural city, especially for foreign visitors and young Japanese.

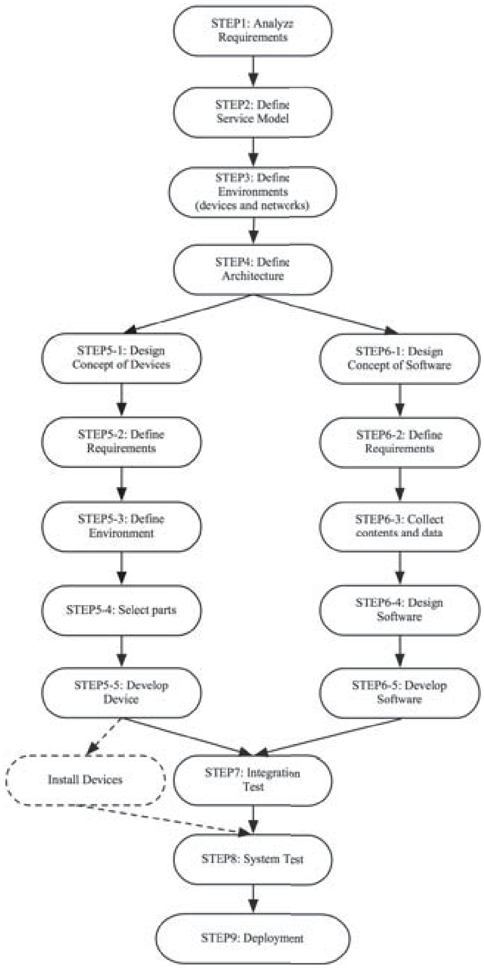


Fig. 1. Design Process.

References

1. http://blog.bluetooth.com/bluetooth-sig-introduces-new-bluetooth-4-1-specification/
2. Yuko Hiramatsu, Fumihiro Sato, Atsushi Ito, Hiroyuki Hatano, Mie Sato, Yu Watanabe, and Akira Sasaki: A Service Model using Bluetooth Low Energy Beacons-To Provide Tourism Information of Traditional Cultural Sites. Service Computation 2016, March 2016
3. The Ministry of Internal Affairs and Communications, Strategic Information and Communications R&D Promotion Programme, [Online]. Available from: http://www.soumu.go.jp/main_sosiki/joho_tsusin/scope/, [Nov. 30, 2016].

A Study of Optimization Method for Information Delivery using BLE Beacon

Hiromu SAIJO Atsushi ITO Hiroyuki HATANO

Information System Science Department, Graduate School of Engineering,
Utsunomiya University, 7-1-2 Yoto, Utsunomiya, Tochigi, 321-8505, Japan
gashjp1994@gmail.com
{at.ito, hatano}@is.utsunomiya-u.ac.jp

In recent years, development of new services using smartphones and the peripherals are carried out rapidly. Recently, BLE(Bluetooth Low Energy) beacon [1] that has lower power consumption comparing to traditional Bluetooth has been popular. BLE beacon transmits UUID to a smartphone. If a smartphone receives UUID from a beacon, the smartphone can display information such as coupon of shops corresponding to the received UUID.

There are some services to use BLE beacon for marketing [2], however it is still unclear that to decide the most effective timing to send advertisement information to increase sales.

Based on these background, we started a study to select the most effective message providing point(=beacon) from beacon network. Figure 1 shows a sample beacon network. A beacon network contains several beacons (b_i). One of the beacons is called "conversion beacon" that is the destination point. Our research is how to find the most appropriate point (beacon) to send an advertising message to persuade a user to visit the destination point.

In addition, we decided to add one restriction in our system. Our system sends only one advertisement message can be send in a day. Since if we can send many advertisements to a user, it may be possible to persuade the user to visit there, however, the user soon un-install such application from his smartphone to avoid annoying message.

For example, if a coffee shop would like to increase the number of visitors (in this case that is the location of conversion beacon), the shop owner would like to send an advertisement message. It may be difficult to decide the most appropriate point to send an advertisement. Our system can support such decision.

In this research, we decided to define the following problem; How to calculate coversion rate of each beacons in a network. Conversion rate means the possibility to persuade a user to visit

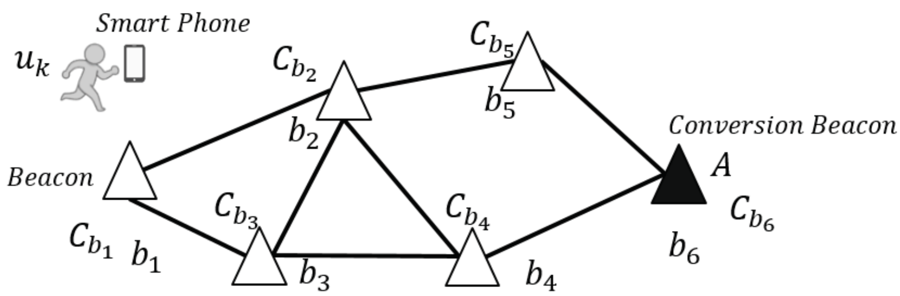


Figure 1 Beacon Network.

the destination (conversion beacon). As described in Figure 1, each beacon has conversion rate (C_{bi}).

Conversion rate is the transition probability between two beacons. This probability is calculated based on the set of user log.

Figure 2 shows the outline of decision process to decide the message delivery point that is called "conversion point".

Step1: First we calculate conversion rate $\boldsymbol{C} = \{C_{bi}\}$ based on user log.

Step2: Then we decide the route R where a user is walking based on user log.

Step3: At last, we can decide the conversion point as maximum C_{bi} on R that is decided in Step2.

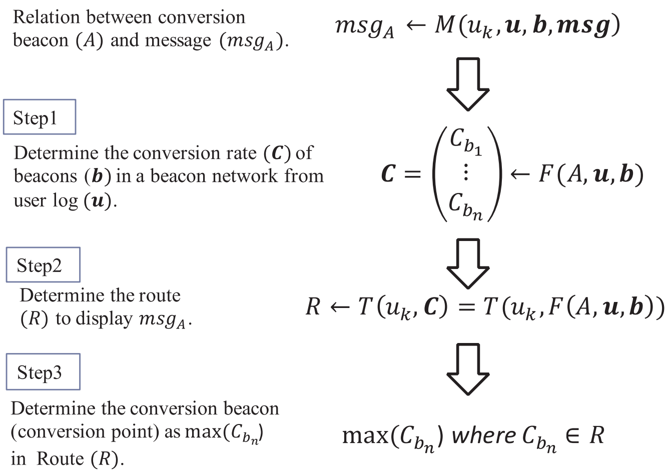


Figure 2 Outline of calculating conversion rate in a beacon network.

In the remaining part of this paper, we will explain the result of our experiment. We installed about 40 beacons in the building of information science department and developed an application to navigate them in the building for visitors who visited out university to attend school festival that was held in the last July. The application has a function to send a message to users to recommend to visit a specific laboratory. With the ability to send a message, when to send a message was verified.

We tested the appropriate timing to send message to persuade visitors to guide to the specific room. We set two timing to send message, (1) one is just after starting tour to visit laboratories, (2) another is near the room to visit. 43 people, mainly high school students, participated this test. In this case, the timing (1) is more effective than (2).

The detail of the result will be described in the final paper.

References

[1] http://blog.bluetooth.com/bluetooth-sig-introduces-new-bluetooth-4-1-specification/
[2] https://beaconbank.jp/

Data-Driven Maritime Processes Management Using Dynamically Reconfigurable Executable Models

Tomáš Richta[1], Hao Wang[2], Ottar Osen[2], Arne Styve[2], and Vladimír Janoušek[1]

[1] Faculty of Information Technology,
Brno University of Technology,
IT4Innovations Centre of Excellence
612 66 Brno, The Czech Republic
{irichta,janousek}@fit.vutbr.cz
[2] Big Data Lab, Faculty of Eng. & Natural Sci.
Norwegian Univ. of Sci. & Tech.
Aalesund, 6009 Norway
{hawa,ottar.osen,asty}@ntnu.no

Abstract

In this paper, we aim to describe the decision support system for maritime traffic and operations, based on the formal models and driven by data from the environment. An expert system is based on knowledge of experts from a specific domain in order to assist in the decision making process. Production rules could form the pieces of the knowledge represented under a condition-action format [4]. In this paper we focus on the maritime domain and therefore the specific impact of this domain on the language used for definition of rules will be discussed. Some of these ideas were already addressed, e.g. by Ludwig Ostermayer and his colleagues [3]. To handle the complexity of the system description, we work with the decomposition of the domain to a set of abstraction levels by which specific views of the system could be separated. At each level, there is a specific domain language for rules expression. These ideas could be found also in some literature about expert systems like e.g. [2].

The most abstract point of view is the aquaculture management. On the other hand, from the ship engineering point of view, the whole process consists of many devices, that should be controlled and maintained by the people. Software engineering point of view operates over operations like reading and converting bytes of data, storing them into variables, arrays, collections, databases, etc. Therefore for the purposes of complex trading processes management we need to cover all levels of abstraction by some means suitable to model and automate the operations on each particular level.

We use salmon farming in Norway as the case study. Aquaculture is a profitable business dominated by big companies. In order to maximise the profit there are continuous efforts put on optimising the process. Examples include the optimisation of: time at sea (fast growth), fodder, produced biomass vs fodder volume, harvesting time, medicine, O_2 usage and fish quality. In order to succeed, a close control of biomass production at every step in the process is vital. All the involved devices are sources of data for the decision support system.

Recently, vessel builders started to adopt new sensor technology by installing different sensors for different components on board a vehicle and transmit data using satellite communications to land-based service centres, e.g., *HEalth MOnitoring System* (HEMOS) by Rolls-Royce Marine AS. These systems provide more accurate and timely operational data, but they also introduce new danger to the operations: *information overload problem* (IOP) [1],[6],[7] – the crew members receive a large volume of monitoring information and alert messages that s/he can easily overlook important/vital ones. One of the main issues is then an effective reduction of data volume.

In this paper, we focus on the definition of data propagation rules used for the system specification, which are modeled as Reference Petri nets and interpreted by the PNOS [5] engine. This approach brings formal foundations to the system definition as well as dynamic reconfigurability to its runtime and operation.

References

1. Keim, D., Andrienko, G., Fekete, J.D., Görg, C., Kohlhammer, J., Melançon, G.: Visual analytics: Definition, Process, and Challenges. In: Information Visualization. LNCS, vol. 4950, pp. 154–175. Springer (2008)
2. Nikolopoulos, C.: Expert Systems: Introduction to First and Second Generation and Hybrid Knowledge Based Systems. Marcel Dekker, Inc., New York, NY, USA, 1st edn. (1997)
3. Ostermayer, L., Seipel, D.: A prolog framework for integrating business rules into java applications. In: Nalepa, G.J., Baumeister, J. (eds.) Proceedings of 9th Workshop on Knowledge Engineering and Software Engineering (KESE9) co-located with the 36th German Conference on Artificial Intelligence (KI2013), Koblenz, Germany, September 17, 2013. CEUR Workshop Proceedings, vol. 1070. CEUR-WS.org (2013)
4. Ray, C., Grancher, A., Thibaud, R., Etienne, L.: Spatio-temporal rule-based analysis of maritime traffic. In: Third Conference on Ocean & Coastal Observation: Sensors and Observing Systems, Numerical Models and Information (OCOSS). pp. 171–178 (2013)
5. Richta, T., Janousek, V., Kocí, R.: Dynamic software architecture for distributed embedded control systems. In: Proceedings of the International Workshop on Petri Nets and Software Engineering (PNSE'15), including the International Workshop on Petri Nets for Adaptive Discrete Event Control Systems (ADECS 2015) A satellite event of the conferences: 36th International Conference on Application and Theory of Petri Nets and Concurrency Petri Nets 2015 and 15th International Conference on Application of Concurrency to System Design ACSD 2015, Brussels, Belgium, June 22-23, 2015. pp. 133–150 (2015)
6. Wang, H., Fossen, S., Han, F., Hameed, I.A.: Data-driven Identification and Analysis of Propeller Ventilation. In: Oceans 2016: MTS/IEEE Oceans Conference (2016)
7. Wang, H., Zhuge, X., Strazdins, G., Wei, Z., Li, G., Zhang, H.: Data Integration and Visualisation for Demanding Marine Operations. In: Oceans 2016: MTS/IEEE Oceans Conference (2016)

The neural system of monitoring and evaluating the parameters of the elements of an intelligent building.

Extended Abstract

Andrzej Stachno

Department of Control Systems and Mechatronics,
Wroclaw University of Science and Technology, Wroclaw, Poland
{andrzej.stachno@pwr.edu.pl}

Keywords: Artificial Neuron Networks, FFT, Forecasting, Successive Values of a Time Series, Environmental Measurements in an Intelligent Building.

Extended Abstract

In the intelligent buildings more and more features are dependent on the proper operation of equipment powered by electricity. These devices are necessary to maintain thermal comfort, maintaining constant light, ensuring the safety of building occupants and the safety of the technical building and other functions performed by the automation system [4]. All control functions of the building automation, are now dependent on the proper operation of electrical equipment. Any damage to these devices impact very negatively on the functioning of the building is needed for immediate repair or replacement. In many cases, the failure prevents the use of the building. Eg. Heating failure, access control system or lighting system. Associated with the large financial losses. Possible equipment failures can, however, provide an analysis of how they operate. Monitoring and analysis of the parameters of the power of individual electrical devices allow you to isolate specific to each receiver electrical performance. Any deviations from the stable working conditions, can be recorded by the neural system of monitoring and evaluating the operating parameters (NSMEOP). The system includes:
- analyzers operating parameters,
- adaptive measuring system
- neural decision algorithm.

Analysis of anomalies parameters of the power of these devices, their productivity and efficiency, allows to predict how their future work. Due to the large number of such devices, it is necessary to automate the function, and forecasting. Additional changing working conditions for building systems, depending on the internal and external environmental parameters such as temperature external, internal, humidity, carbon dioxide concentration, the current power consumption and distortion power generated by the unit operated in the building. Mechanism for such an analysis is the implementation of an adaptive prediction algorithm using artificial neural networks [5]. This method allows the adaptation of the decision-making mechanism to the current operating conditions of controlled devices. The test parameters include measurements of physical quantities showing the operation of the device. For example, the studied parameters central air-conditioning and ventilation are charged electricity, forcing the air flow and the same air flow. Based on the analysis of changes in these values and providing them with time series [1] [3], it is possible to designate time wear and tear consumables (eg. Air filters) and mechanical (eg. Bearing fan) [2]. An additional advantage of the power analysis, is to identify typical problems and corresponding deformation parameters of power. Based on the previously prepared template, the artificial neural network to identify damage to the component or designate on the basis of the forecast using the MWF [5] projected a critical time element damage or subsystem control. Early prediction of a situation of failure contributes significantly to the comfort and safety of users of intelligent building.

References

1. Stanley N., Eugene H.: An Introduction to Econophysics. Correlations and Complexity in Finance, PWN, 2001.
2. Peitgen H.O., Jurgens H., Saupe D.: Introduction to Fractals and Chaos, PWN, 2002.
3. Technical Analysis of the Financial Markets, WIG PRESS, 1999.
4. Jabłoński A.: Intelligent buildings as distributed information systems. CASYS: International Journal of Computing Anticipatory Systems. vol. 21, s. 385-394, Liege,2008.
5. Stachno Andrzej, Jabłoński Andrzej: Hybrid method for forecasting next values of time series for intelligent building control / Andrzej Stachno and Andrzej Jabłonski [i in.]. W: Computer aided systems theory - EUROCAST 2015 : 15th International Conference, Las Palmas de Gran Canaria, Spain, February 8-13, 2015 : revised selected papers. Pt. 1 / Roberto Moreno-Díaz, Franz Pichler, Alexis Quesada-Arencibia (eds.). Berlin; Heidelberg: Springer, cop. 2015. s. 822-829,
(Lecture Notes in Computer Science, ISSN 0302-9743; vol. 9520)

Cloud Computing in Education at the Wroclaw University of Science and Technology

Jerzy Kotowki and Jacek Oko

Wrocław University of Science and Technology
11/17 Janiszewskiego, 50-372 Wrocław, Poland
{jerzy.kotowski,jacek.oko}@pwr.edu.pl

Extended abstract

1 Academic Secondary School at WRUST

The offer of the Complex of Academic Secondary Schools of Wrocaw Uni-versity of Science and Technology is aimed at pupils across Poland who are interested in the development of their knowledge and skills related to exact and technical sciences. The complex is a state school and there is no tuition fee.

The Complex:

- pursues the goal of preparing students to creative and responsible life by shaping childrens minds and characters so as young people could combine re-spect for universal values with the challenges of the modern world;
- wants to form people who are open-minded and inquisitive, it would like to inspire them and help to pose clever questions and to search for the answers;
- would like its students to seek knowledge and wisdom with passion and to be ready for education as well as social challenges all their lives.

In its service to the society, the school conducts its mission by offering high quality education and responsible upbringing. Its goal is formation of creative and inquisitive minds, presenting models of professional and civic behaviour, helping its alumni achieve goals. All employees of the Complex of Academic Schools of WrUST work reliably in the atmosphere of cooperation and mutual kindness, observing moral and ethical standards, they respect for legal regulations and the school statute. At WRUST we show due respect to our Almae Matris.

Learning facilities

The Complex of Academic Schools WRUST is located in building C-13, at Wybrzee Wyspiaskiego St. A special feature of this building are round, irregularly distributed windows (the design authors were inspired by a punched tape). The building was awarded a special prize in the Lower Silesian Province Competition. Schools are located on the 3rd and 4th floors of C-13. All classrooms are equipped with computers and multimedia projectors thanks to which our teachers can used modern teaching materials, such as CD-ROMs, multimedia boards or e-course books. The school has high class equipment for robotics and electronic systems construction classes (for secondary school students) with elements of programming (for junior secondary school students). All students have access to specialist equipment the same which is used by university students. This allows them such subjects as physics, chemistry or technology.

Wrocaw University of Science and Technology aims at making an e-learning platform available to students. There would be teaching materials developed by teachers, mock tests as well as some space for students to exchange views and experience related to studying. The building is adapted for the needs of the disabled.

The teachers employed at the Complex of Academic Schools of WrUST have work experience with youth. Earlier many of them worked in the best junior secondary and secondary schools in Wroclaw.

Academy of Young Discoverers

The Academy of Young Discoverers is a cycle of popular science lectures for children. The participants are children from 7 to 14 years of age.

During these meetings children learn about various issues related to physics, mathematics, technology, etc. To make the meetings more interesting a lot of pic-tures and photos as well as short films are used during these meetings. At the end of the semester or school year each participant receives a graduate diploma of the Academy of Young Discoverers. There is no tuition for any classes. The project is financed by the University and the Boeing Company. On 25 October 2008 the of-ficial opening ceremony of the of the Academy of Young Discoverers took place in the main assembly hall of WRUST.

Childrens University

In Wrocaw children of 6 to 13 years of age learn the same subjects as stu-dents. Moreover, they study in the same classrooms and have student records. All this takes place at the Childrens University. The idea was developed by a foundation of the same name. Last year there were one thousand students in Lower Silesia. Lecturers use special methods to transfer difficult knowledge in an accessible way. Currently negotiations related to abolishing the tuition fee are held at WrUST. Pursuant to the university mission studying should be offered free of charge and unfortunately at the moment this is not the case.

References

1. Brzozowska A. J, Greblicki J., Kotowski J.: Cloud computing in education-al applications: methods of virtual desktops deployment. Computer aided systems theory - EUROCAST 2011, Las Palmas de Gran Canaria, Spain.

A study of Precedent Retrieval System for Civil Trial

Yuya Kiryu[1], Atsushi Ito[1], Takehiko Kasahara[2],
Hiroyuki Hatano[1]

[1]Utsunomiya University, 7-1-2 Yoto, Utsunomiya, Tochigi, 321-8505, Japan
u81645@gmail.com,
{at.ito, hatano}@is.utsunomiya-u.ac.jp
[2]Toin Yokohama University, 1614 Kurogane-cyo, Aoba-ku, Yokohama-shi, Kanagawa,
225-8503, Japan, kasahara@toin.ac.jp

Recently, ICT(Information and Communication Technology) has been adopted for use by the judiciaries in many countries such as Singapore and a specialized paperless Cybercrime court in India, in response to the global changes in the economy and politics. Due to politics typified by the TPP (Trans-Pacific Partnership), the progress of globalization of the economy, an increase in commerce individuals do with overseas through the Internet, even in Japan, legal issues which also includes international and personal level is expected to be increase future. It is urgently necessary for Japanese judiciary to adopt ICT to catch up with the global trend.

In Japan, "Judicial Reform Promotion Plan" was decided in 2002[1] to realize "ubiquitous access" for justice. The purpose of this plan is to prepare environment to use judicial system by ordinary people subjectively and autonomously. The idea has not enough realized yet. For example, judicial records are not yet fully opened and only some decisions are opened. Also, the retrieval tool is not well designed for ordinary people.

In a civil action, in order to obtain a profitable legal effect, it is necessary for parties to find sentences in law, as a weapon to win, and provide presupposed ultimate facts to satisfy each law. When we take an action, we must describe a cause of the demand in accordance with these presupposed ultimate facts. It is too difficult for ordinary people to search and decide it, since they don't have legal knowledge.

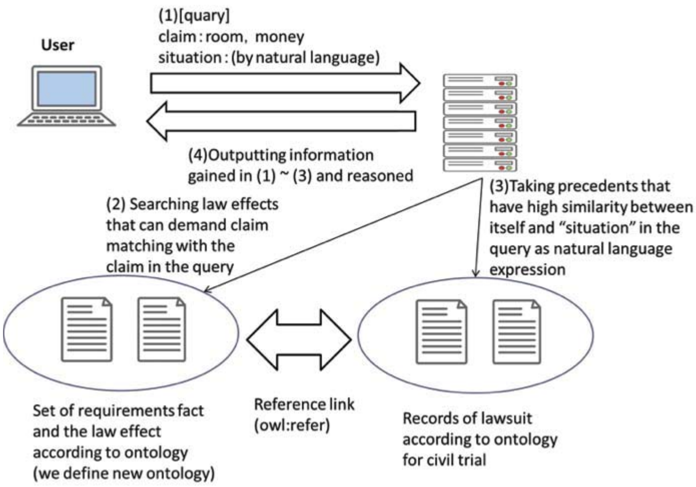


Figure 1 Structure of proposed system

Therefore, this paper describes what institutions of lawsuit require and it is too difficult for except judicial officer to do it. To solve this problem, we propose a system (Figure 1) which uses ontology for writing and reading legal documents (Proposed system is based on a system based on ontology that we suggested before [2]). Moreover, we use OWL and SPARQL as ontology language and query language.

In addition, we usually assume that there is reference relations between a precedent (records of a lawsuit) and a law (a set of presupposed ultimate facts and law effect). We need meta data to make such reference, however, they are not added to an exhibited precedent at the present. The study of the reference method identification to parse precedent to plain sentence is conducted now, but the precision is not satisfactory. It is necessary to prepare for reference relations manually when we start to use this system. Once this system is started, reference relations can be added automatically, because if a law suggested on proposed system is used, then records of a lawsuit is generated automatically. It is clear that high quality data can be generated in this sequence, once this flow is invoked.

The rough structure of proposed system is as follows: (1) throwing " claim and "the situation" as a query, (2) searching law effects that can demand claim matching with the claim in the query, (3) taking precedents that have high similarity between itself and “situation” in the query as natural language expression, (4) outputting information gained in (1) - (3) and reasoned form this.

In proposed system, we use ontology we defined newly. We call it “ontology for interaction between fact and law”. We can inference “major difference in requirements of each law” and “laws that have same effects and fact” with it. This ontology is composed of two ontologies that are “Law term ontology” and “Requirement and Effect ontology”. If the system search “major difference in requirements of each law” and display them, users can choose suitable information easily without reading every proposed presupposed ultimate facts. Also, if users who are plaintiffs can find “laws that have same effects and fact”, it is profitable for plaintiffs to use them since defendants lose a suit if they cannot reject all claims. Japanese examples of famous rights of conflict to claim are as follows: “Debt default and Tort”, “Right stemming from title and Right to claim in the contract”, “Tort and Un-just enrichment claim” and “Right stemming from title and Unjust enrichment claim”.

This system allows users to find laws they want and precedents that are similar to situation they suppose. However, it is difficult for the system to recognize the situation enough because the proposed system simply searches similar precedents by natural language processing from the sentence that described the situation users consider. Therefore, there is a way that we make ontology that expresses the “situation” as the next step and manage it, but we cannot expect that general users have knowledge of the ontology description. As the system that users can describe ontology easily, we are going to examine following two ways in future. (1) Converting a sentence to express the situation users describe into the ontology form. (2) To allow users describe ontology graphically described. In the former case, a sentence whose grammar is error cause problems since input sentence is used for natural language processing. Therefore, it is difficult to expect precision in any case. In the latter case, a good tool of the user-friendliness is demanded.

References

[1]http://www.kantei.go.jp/jp/singi/sihou/keikaku/020319keikaku.html (in Japanese) [Dec. 18, 2016]
[2]Yuya Kiryu, Atsushi Ito, Takehiko Kasahara, Yu Watanabe, Masahiro Fujii, Hiroyuki Hatano, “A Study of Ontology for Civil Trial “, JURISIN2015(2015)

Cooperating on innovation to make CENTRAL EUROPE more competitive

Manuel Brunner [1], Bernd Spiegelberger[2]

[1]Business Upper Austria – OÖ Wirtschaftsagentur GmbH; Mechatronik-Cluster
Hafenstraße 47-51, 4020 Linz, Austria
manuel.brunner@biz-up.at

[2]ITQ GmbH
Parkring 4, 85748 Garching b. München, Germany
spiegelberger@itq.de

Motivation

Central Europe area is the backbone of EU advanced manufacturing industry. Regions like Emilia-Romagna, Veneto, Upper Austria, Bayern have long global leadership while in others (Lower Silesian, Košice, Eastern CZ) the potential has been unleashed by the recent access to EU, new R&D infrastructures and foreign direct investment. In these Regions the advanced manufacturing sector, such as automotive, automation or IT is characterized by strong intercontinental business relationship.

At the same time, this dynamic business environment and the local-based linkages of universities and companies have encouraged R&D investments in public & private sector, making these territories outstanding R&D poles in the new techs for mechatronics in CE and EU space.

However, in the same NUCLEI [1] regions, innovation support services are limited in the scope as they are mainly focused on doing brokerage and tech-transfer within a given territorial domain. Especially the transnational cooperation is poor. This traditional “local-based” approach to tech-transfer is currently a limit. It doesn't help rapid transfer of new concepts into industrial exploitation, especially for SMEs, while R&D performers from different regions are poorly connected with each other.

So innovation support services commissioned by companies are inefficient, often duplicate efforts and are not always responding to the time-to-market requirements. In short, the traditional innovation-management service is obsolete.

Objective

Main objective of NUCLEI is to change the traditional innovation management services for CE advanced manufacturing industries from a “local-based” support approach to a transnational pool of knowledge supporting innovation in businesses, beyond own regional borders. NUCLEI contributes to CE goals by enhancing economic & technological interdependences among seven S3-manufacturing CE Regions and encourages more effective transnational linkages in automotive, automation and IT. Main beneficiaries are the CE manufacturing companies and indirectly the CE public and private labs. Project results end up with an augmentation of R&D expenditure in the industrial supply chain and higher number of SMEs introducing product or process innovation facilitated by NUCLEI open innovation environment. All these measures together will accelerate the innovation process and an inventions time to market.

NUCLEI federates in one system various and top industrial competences and leads to better matching concepts for key enabling technologies with companies' demands. As a result, an increase of commercial exploitation of R&D by CE labs and fostered linkages and business deals among innovation players (clusters, innovation centers, private & public research institutes, etc.) are expected.

NUCLEI Approach

Obsolescence of traditional innovation management business model is widely recognized by industrial players, especially if compared with the three main factors that are challenging this sector:

- Gain of market segments by traditional EU-manufacturing competitors such as US, Israel or S.Korea. New ones in South America and Africa as well as the influence of low-cost products from Asia.
- Increasing need for flexible, rapid and customized solutions by the mechatronics industries due to the increase of complexity of the engineering processes and necessary interdisciplinary collaboration;
- Need for standardized technical regulations and internal market rules.

Upon these common challenge, and upcoming trends like the digitalization of the supply chain and the product lifecycle in NUCLEI areas, the companies claim for introducing new practices compared to the traditional tech-transfer & tech-diagnostic in use by each industrial pole. The modification of innovation management services must evolve to a closer cooperation among the CE excellence nodes such as factories, clusters, innovation centers, private and public research institutes and others as way towards a real transnational value supply chain of mechatronic components, automation & robotic technology and new materials. Beside the new practices, companies as well as the other mentioned partners also require a unique approach for handling the introduction of new measures.

Three practices are introduced by NUCLEI to spark innovation compared to the current state of art:

1. A joint database cloud to make a quick industrial-oriented screening of the most promising R&D results borne in CE labs for the CE advanced manufacturing sector
2. Three pilot actions offering a broad collaborative environment to match make companies R&D requirements with the excellence nodes.
   (a) Action 1: Standardization of energy class of industrial plant-machineries
   (b) Action 2: Draft for a standardized IOT interface for production plants
   (c) Action 3: Analysis of data security standards for cloud platforms
3. Tailor-made action plans for the expansion of the NUCLEI i-services within each region.

References

1. CE318 – Interreg CENTRAL EUROPE - Call 1 (2016) Project Title: "Network of Technology Transfer Nodes for Enhanced open Innovation in the Central European advanced manufacturing and processing industry - NUCLEI".

Education as a Key in Mechatronic Engineering

Dr.-Ing. Rainer Stetter

ITQ GmbH, 85748 Garching bei München, Germany

Abstract. Due to an increasing complexity in mechatronical development projects and thus required interdisciplinary cooperation of domain engineers, highly integrated, but still easy to use development methods have to be established. The use of agile concepts promise improved product quality by advanced collaboration techniques, which, combined with mechatronical simulation throughout the entire development process, elaborate the final results. This is shown by an interdisciplinary and international student team for the development of a modular production line.

1 Introduction

The current situation in the field of mechanical and plant engineering is characterized by short development cycles, a high demand for diverse and individual products. Manufactures react to this situation with a deep integration of software into their products. This is both a chance and a threat, since the dependencies of the involved disciplines are dramatically increased, which results in a higher product complexity demanding a systematic approach of the software development process. Education takes in a central role in order to cope with upcoming challenges. Scenario based learning (hands-on) helps to understand the inner coherence of complex systems [MS1]. In mechatronics, where multiple disciplines need to find common ground practical experience is essential. Such learning techniques improve the learning process positively [SC1].

2 Mi5 as Technical Basis for Education and Awareness

The challenge of companies is mastering the productivity in production and engineering. The development of mechatronic products must take place faster and at higher quality in order to be successful with an increasing innovation and cost pressure. ITQ initiated the project Showcase Mi5 with partners from industry, research and education [MI5]. Mi5 stands for ideal type of Mechatronical Engineering, where the five "is" stand for innovative, interdisciplinary, international, incremental, iterative. A group of more than 20 interdisciplinary and international students developed a modular and smart production line for the fabrication of different comestible goods, see Fig. 1. The used development process illustrates the application and advancements of development methodologies in a highly interdisciplinary environment.

2.1 Touchable Engineering

The Mi5 team makes modern engineering touchable. Development effort increases due to complex technical requirements. In order to cope with that complexity, an enhancement of development methodologies is necessary. This process is visualized by the development project Mi5, which represents a production line close to reality. All components and development steps satisfy the requirements of modern industrial production processes, hence it can be seen as scheme for mechatronic development.

In the demo plant there are communication and manufacturing technologies of automation suppliers in use without any exception. This way is shown how the idea of Industry 4.0 can be realized by a combination of current standards.

Several approaches of mechatronic development methodologies were combined with methods of project organization during engineering of Mi5. On the one hand the classical methodology Quality Gate Model was used for cross project organization, where on the other hand agile methods known from software engineering were applied. The process of a homogeneous mechatronic development was run through step by step. All gained experiences were fed back into the continuous optimization of the process. This ongoing process of adaptation advanced iteratively over all Mi5 project phases.

2.2 Engineering and Technical Design

Machine time during engineering will be become smaller and smaller since time to market constantly decreases. The Mi5 demo plant was built within 6 months from idea to product. The technical components were delivered 10 days before the trade fair SPS/IPC/Drives 2014. The assembly of the system was done within 3 days, integration and system start could be done within only a few hours. This became possible by the extensive use of simulation during development. The simulation model has the exact behavior of the real plant and was used for real time simulation of the production process, for implementation and optimization of initialization routines, process and recipe handling as well as a visualization of the plant status. Software development of all modules could be performed on this Hardware-in-the-Loop (HiL) test environment.

All modules communicate among each other over a central OPC UA server. Modules can register and deregister on the server, which enables modular reconfiguration during production process. The control is done by a so called process tool, which has the ability to automatically identify all available modules and integrates them the production process. The demo plant consists out of different modules, which produce cocktails (fluids) and cookie burgers (solid) filled with cream (viscose) in modularly combinable process steps. For transportation the eXtended Transport System (XTS) from Beckhoff Automation is used. It can position movers individually on a circular path. Adapters are mounted on the movers, which can support the production process by vertical movements.

2.3 Mixed Reality Scenario for Development and Runtime

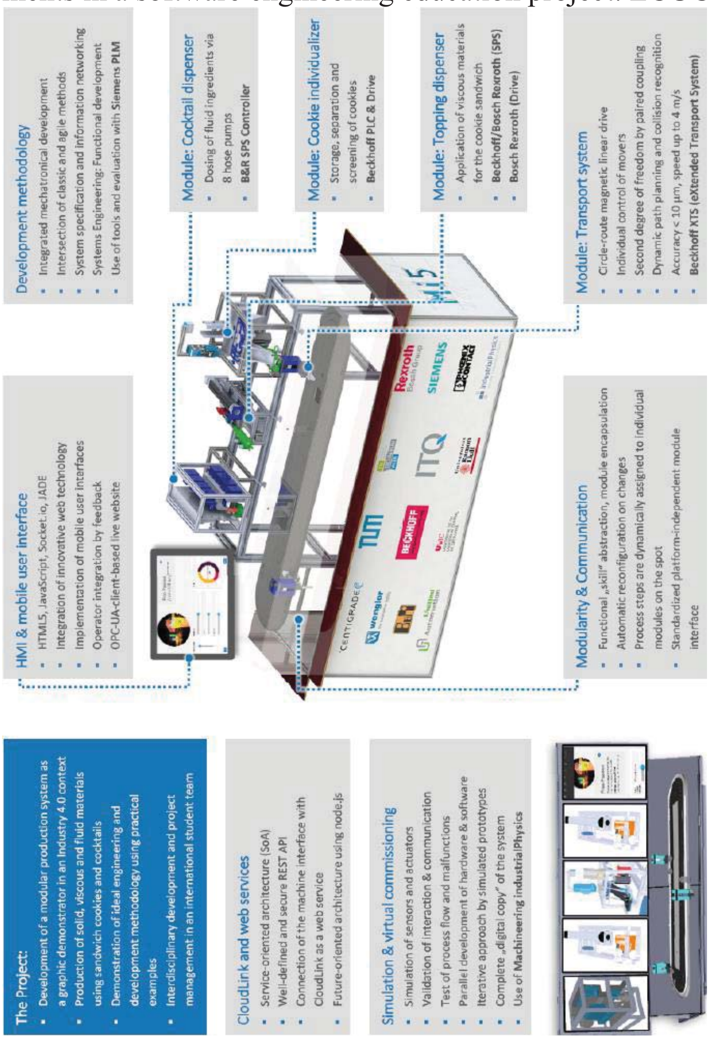
The concept of Mi5 is laid out such that the system can be run completely in reality, but it also be simulated completely. Both systems (real and virtual) can be executed in parallel. The main clue is system execution in mixed reality mode, see Fig 2. Each module of Mi5 can be used for production in real or virtual mode based on the unique Representational State Transfer (REST) interface. A big proof that system architecture and design for development in machine and plant automation is the independence from steel and iron. This enables early and distributed (location, supplier) development of system functionality.

3 Summary and Outlook

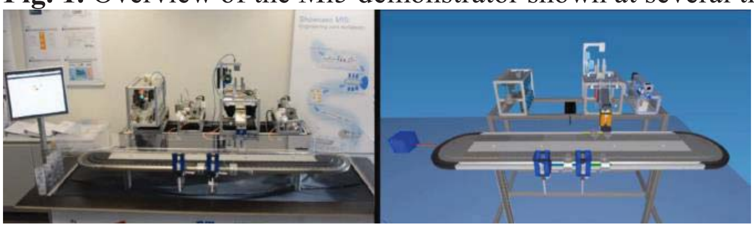
Mi5 is a constantly growing education project, where students, engineers and researches can exploit state of the art topics in mechatronic and especially software engineering. In cooperation with the company “Dr. Stetter ITQ” the project Mi5 expanded to Gran Canaria. The innovation lab established there, is focusing on research on promising topics such as Green Energy, Smart Homes, Smart Farming, Smart Mobility and Autonomous Driving. In doing so, makeathons are one key enabler as well for the development of innovative ideas as for a modern education. So a makeathon in September 2016 gave first answers to the question: “How can digital technology and connected devices help to build a smart and green island?”

References.

- [MI5] Mi5, ITQ GmbH: Online documentation of the Mi5 team, project and development methodology. http://www.projectmi5.com (2016)
- [MS1] Mariappan, J., Shih, A., and Schrader, P.: Use of Scenario-Based Learning Approach in Teaching Statics. Proceedings of the ASEE Conference (2004)
- [SC1] Schumm, M., Soska, A., Joseph, S., Reschke, M. Mottok, J., Niemetz, M., Schroll-Decker, I.: Comparison of frontal lecture and workshop learning arrangements in a software engineering education project. ECUCON (2014)



- **Fig. 1.** Overview of the Mi5 demonstrator shown at several trade fairs



- **Fig. 2.** Mixed reality: reality and simulation run concurrently

A student group at the University of Los Andes for modern mechatronics

Giacomo Barbieri[1] and Florian Pichler[2]

Universidad de Los Andes
Cra. 2 Este No. 19A-40 Bogota, Colombia
g.barbieri@uniandes.edu.co

ITQ GmbH
Parkring 4, 85748 Garching bei Munchen, Germany
pichler@itq.de

1 Introduction

This paper describes two projects of a student group at the University of Los Andes. These projects have the task of providing students the chance to make practical experiences in topics of industrial interest. Moreover, modern tools will be investigated for the developing of interdisciplinary / mechatronic approaches. The projects can be positioned into two research areas:

- *Design for Reuse*: reduce costs and time for the development of production systems through the reuse of already designed mechatronic modules;
- *Smart Farming*: utilize modern Information and Communication Technologies (ICTs) for industrializing and automatizing agriculture operations.

1.1 Modular machine for processing coffee beans

Production systems have shifted from mainly mechanical-based systems to aggregations of cyber-physical systems. Traditionally, a "design-by-discipline" approach was adopted in which every discipline was developed independently and then integrated to generate the final solution. Verification phase was the final activity of the design process leading to high-cost for errors due to their late detection. *Cyber-physical design methodologies* must be investigated in order to reach: (1) concurrent development of the involved disciplines; (2) continuous verification of the solution for an early detection of errors.
Moreover, from one hand complexity of production systems is growing because increasing functionality, flexibility and performance are required. From the other hand, low costs and short time-to-market must be achieved. These requirements can be fulfilled with the realization of *reusable mechatronic modules*.
Modularity is inversely proportional to the number of sensors and actuators, and to the time necessary for modularizing the solution. In fact, the operation of designing a reusable module involves among the others: define modular control code, assure correct functionality for different environments, and define variation

range for module parameters and operational modes. All these activities increase developing time with respect to the realization of ”ad-hoc” solutions. However, once a library of modules has been realized, development time and costs are reduced since design activity is limited to the assembly of already tested modules and the verification that the generated system fulfills stakeholder requirements.

Authors think that before identifying an optimal point among level of modularity and system developing time and costs, methodologies for reaching modularity must be investigated. A scaled modular production system for processing coffee beans will be built. The machine will consist of three modules performing toasting, grinding and packaging. The objective of the project will be to investigate:

- Cyber-physical approaches for the development of mechatronic modules;
- Methodologies for realizing a ”plug-and-play” design of production systems starting from the assembly of existing mechatronic modules.

1.2 Automatic sensing of field properties

The increasing utilization of sensors due to the reduction of the cost of electronics, along with the innovations in ICT supporting record and integration of values coming from different sensors through standardized protocols, have brought new opportunities in different domains. Among these, the utilization of *Internet of Thing* approaches in agriculture can be cited.
Authors have investigated at Colombia situation. The recent peace agreement proposal between the government and the FARC organization contains a large section about the goal of industrializing agriculture. Even if the agreement was not successful, this witnesses the interest of Colombian government for the topic.

Authors decided to start focusing on coffee production but the involved concepts can be extended to any cultivation. A long-term project aims to reach an automatic ”digitalization” of the properties of a coffee field. Project consists on:

- *Field properties*: consult specialists for identifying which properties, indexes, target values and acceptable boundaries are important for characterizing the status of a coffee field; e.g. soil pH, humidity and chemical composition, localization of coffee beans ready to be harvested and sick plants, etc.;
- *Collection*: identify sensors, algorithms and processing units for collecting all the relevant field properties;
- *Digitalization*: generation of topology maps for visualizing collected data and for deriving overall field properties; e.g. most productive areas;
- *Automation*: realization of prototypes able to automatically collect field properties. Ground and flight vehicles will be investigated as mobile robots and drones. Moreover, ICT technologies will be studied for implementing the communication among a central station and the collecting units.

The digitalization of the field information will allow understanding issues related to coffee production. As future work, improvement areas will be investigated and solutions will be proposed.

Modular 3D-printed Robots for Education and Training for Industrie 4.0

Dirk Jacob[1], Patrick Haberstroh[2], Dominik Neidhardt[1], Benno Timmermann[1]

[1]Faculty of Electrical Engineering, University of Applied Sciences Kempten, Germany
dirk.jacob@hs-kempten.de
[2]B&R Industrie-Elektronik GmbH, Bad Homburg, Germany
patrick.haberstroh@br-automation.com

Abstract. Robotics as one of the main components of Industrie 4.0 has to be integrated in today's teachings. To provide educational institutions a low-cost but industry-oriented robot system, a modular 3D printed robot kit is developed which can be controlled by an industrial controller or a low-cost PC board.

Keywords: Robotics, 3D printing, teaching

1 Concept of Robotic Training Kit

Robotics is one of the major components of automation technologies within the framework of Industrie 4.0 [1,2]. As robot are programmable handling systems, they are in principle able to adapt to changes of the positions resulting from flexible production tasks [3]. In order to be able to train future engineers on a high level, appropriate learning environments are required. The problem is often that robots on the one hand are very cost-intensive for the procurement of educational institutions such as professional schools or schools for technicians or universities. On the other hand, there is often not enough room in the facilities to be able to operate several robotic systems in parallel.

Based on these limitations, training and practical training hours in robotics for students are often limited to a very short period of time so that training time for this key technology is too short. Small cost-effective robot models for training can be used as a compromise, but they do not have a controller at industry level. Thus, the trainer is able to train a larger number of students, but the students need completely different programming environments and standards in their professional life.

As a solution to this dilemma, a modular construction kit has been developed which can be used to implement different robotic kinematics at low cost. The implemented drive technology allows the control, programming and operation of the robot models by an industrial controller.

With the aid of the developed kinematic kit, it is possible to build different robot kinematics from simple 2- or 3-axis models to more complex 5-axis articulated robot arms. In addition to the standard articulated kinematics, the set-up of a SCARA robot as well as a kinematics of a palletizing robot with 4 degrees of freedom is possible, too.

The individual parts of the kinematics are designed in such a way that they can be produced with 3D printers which are usually available at educational institutions. The drive technology consists of stepping motors in three different performance levels and design sizes. Each motor is supplemented by a gearbox to increase the available torque at the output shaft. The individual components of the kinematics are connected to one another by the drive units, thus completing the overall kinematics. For the cable guidance, corresponding guiding channels are provided in the 3D printing parts. The length of the individual components is, in principle, variable. The standard length of the parts is app. 200 mm, in order to be able to be produced in customary 3D printers. However, the CAD models of the parts are designed in such a way that the component lengths of the individual kinematic components can also be adapted to individual requirements.

An industrial controller from Bernecker + Rainer Industrie Elektronik Ges.mb.H is used to control the robot models. B & R's Software "Automation Studio" is used as programming environment. This uses a so-called "mapp.Technology" to be able to program and control different modular automation systems. Specifically, "mapp.Robotics", a subdomain of "mapp.Technology" is used. It is a software that provides modular function blocks and data structures for robot programming. Under "mapp.Robotics" different predefined kinematics models are available as central objects, which contain all necessary information for the each operated kinematics. These central objects command the basic tasks for robot mechanics, such as the switching on of the arm power or referencing of the axes. For standard models of the kit, predefined configurations are available with the respective kinematics and drives. Thus the robot models can be commissioned and programmed without great effort. For individualization of the configuration, corresponding parameter lists and input aids are available in Automation Studio.

2 Conclusion

The modular robotic kit makes it possible to manufacture cost-effective robotic machines individually as printed models and to operate them with an industrial control system. The modular design of the development environment of the industrial control system also allows the control parameters to be adapted to individual robot configurations. In addition, the robot models can be controlled with available control solutions, such as Raspberry Pi to be individually operated. This provides a variety of possibilities for training and teaching in order to be able to integrate robots as one of the core components of Industrie 4.0 intensively in today's universities and schools.

3 References

1. Huber W (2016) Industrie 4.0 in der Automobilproduktion. Ein Praxisbuch. p. 21. Springer Fachmedien Wiesbaden, Wiesbaden
2. Gilchrist A (2016) Industry 4.0. The Industrial Internet of Things. p. 42. Apress, New York
3. Bauernhansl T, Hompel M ten, Vogel-Heuser B (Hrsg) (2014) Industrie 4.0 in Produktion, Automatisierung und Logistik. Anwendung, Technologien, Migration. p. 13. SpringerLink. Springer Vieweg, Wiesbaden

Task-oriented Programming of Assembly Systems based on self-describing Components

How to Create Cyber-Physical Field Devices

Veit Hammerstingl and Gunther Reinhart

Institute for Machine Tools and Industrial Management (iwb), Technical University of Munich, Boltzmannstr. 15, D-85748 Garching, Germany
Veit.Hammerstingl@tum.de

Abstract. In order to be able to react efficiently to changing customer requirements, the low-cost adaptation of production facilities and their automation components is an increasingly important competitive factor for companies. Cyber-Physical Systems could resolve this problem, as they offer ad-hoc-connectivity and –programmability and therefore reduce necessary changeability efforts. This paper gives an overview of the developed concepts on how to automatically create Digital Factory Twins based on existing production cells. Furthermore the facilitation of these twins is described in terms of an automated matching between required production tasks and available device skills.

Keywords: Plug & Produce, IIoT, CPS, Skills, Digital Twin

1 Problem setting and Scope of Work

In the era of mass customization companies have to cope with more frequent changes to their means of production [1]. This need for reconfiguration is in contrast to the currently long downtimes and high integration efforts of production equipment [2]. In particular, most of the efforts are generated in the software- and IT-based integration steps of automation equipment [3]. This is due to a fragmented market with heterogeneous technologies regarding protocols, interfaces, programming languages and vendor-specific tools. Also each reconfiguration in production reflects not only in a change of hardware but also in an adaptation of the overall production process, its controlling software and its parameters.

Therefore a research necessity to reduce the overall IT integration efforts of automation equipment exists. One approach is the development of Cyber-Physical Systems (CPS), which can automatically setup their communication, describe their capabilities and requirements to other systems as well as automatically adapt to changing environmental conditions. The workshop presents an overview on how to achieve these concepts with standard automation devices and how these concepts can be used to program production processes in a hardware neutral manner.

2 Automatic Integration and Self-Description of Field Devices

Based on a production cell for the assembly of LED lamps, a recursive search algorithm was developed, which identifies devices in heterogeneous networks. Since most current sensors and actuators are primitive, i.e. they don't offer a comprehensive self-description or standardised access, a driver-based approach is used. In the first step devices are identified in a network due to their unique features (e.g. MAC address). Next their corresponding access driver is loaded which encapsulates the technology-specific calls and offers a unified access for superior software. Via this driver each device is asked if it offers underlying sub-networks (like in the case of a PLC or robot). In that case, a related protocol driver is loaded which abstracts the specific protocol commands and offers unified access to the network. Each found device is integrated in its superior controller system. Also for each device the associated Digital Twin is loaded from a database and made publically accessible via OPC UA. [3]

The Digital Twin is a standardised information model which describes the properties and capabilities of a production component. Especially the structural and semantical definition of production capabilities (also "skills") were part of the research. With these two concepts all devices can now be accessed in a standardized manner and the aggregation of all accessible servers offers a unified Digital Factory Twin.

3 Task-Oriented Programming based on Automatic Field Device Orchestration

In a following step, a software tool was developed where user could manually specify production processes based on functional primitives (e.g. "Move part", "Detect colour"). These process steps can be automatically matched with the device capabilities of the formerly created Digital Factory Twin. This allows an automatic generation of the overall production software. Since the production sequence is described technologically independent, several different comparison types have to be taken into account (e.g. semantical, technological, geometrical), to determine if a device is suitable for the desired production step.

References

1. E. Abele and G. Reinhart, Zukunft der Produktion: Herausforderungen, Forschungsfelder, Chancen. München: Hanser, 2011.
2. G. Reinhart and S. Krug, "Current state model for easy reconfiguration of robot systems and offline-programming-environments," in Robotics (ISR), 2010 41st International Symposium on and 2010 6th German Conference on Robotics (ROBOTIK).
3. Hammerstingl, Veit; Reinhart, Gunther: "Unified Plug and Produce Architecture in Industrial Environments", In: 2015 IEEE International Conference on Industrial Technology, 17.-19.03.2015, Seville, Spain

Selection of Appropriate Interaction Technologies for Industrial Applications

Christoph Richter and Gunther Reinhart

Fraunhofer Research Institution for Casting, Composite and Processing Technology
Augsburg, Germany
christoph.richter@igcv.fraunhofer.de

1 Extended Abstract

Due to current trends in machinery and plant engineering, like for example increasing product individuality, enterprises need to be innovative even in sectors that do not fit to their actual core competencies [1]. The application of intuitive user interfaces is one recent example with an enormous innovation potential since the user interface is a central interaction point for the customer of a certain machine or plant. For this reason, many enterprises are striving to apply innovative interaction technologies in order to distinguish themselves from competitors [2]. In particular, new interaction technologies, which established themselves in the consumer goods area over the last years (for example mobile multi-touch devices), become more and more important in industrial environments nowadays. But due to different circumstances within these two areas (for example in regard of robustness) a direct usage of consumer good technologies within industrial use cases can barely be realized. The decision of choosing an appropriate interaction technology depends on many different factors, which reach from the production process itself to the entire company strategy. For this reason, a novel approach to select an appropriate interaction technology for a specific machine or plant is presented within this paper.

Whilst previous approaches in this field (e.g. [3-5]) just address a collection of possible selection criteria or a classification of existing interaction technologies, the central element of this approach is an influence matrix, wherein formalized selection criteria of different stakeholders are opposed to formalized classification criteria of interaction technologies. For the actual application of this matrix users characterize their industrial application scenario using the formalized selection criteria and get key features for an appropriate interaction technology as a result. Afterwards these key features are matched to actual interaction technologies in order to determine which technology fits to the respective industrial application scenario.

The approach outlined in the last paragraph was elaborated within a particular research project, where companies from different industries (machinery and plant, software and usability engineering) focused on several topics in order to introduce intuitive and innovative user interfaces in the area of machinery and plant engineering.

Hence, the elaborated influence matrix with its formalized selection and classification criteria was continuously discussed with experts in order to ensure and optimize the significance for real industrial application scenarios. In addition, the approach was evaluated using the scenario of an industrial-close material transportation and stamping unit. The main results of this evaluation are also presented within this paper. Finally, the entire approach is critically discussed in regard of strengths and possible drawbacks and an outlook to future enhancements is given.

2 Acknowledgement

The authors would like to thank the German Federal Ministry of Education and Research (BMBF) for the sponsoring of the research project PEBeMA (Funding code: 01IS15023C).

3 References

1. M. Garetti and M. Taisch, "Sustainable manufacturing: trends and research challenges," Production Planning & Control, vol. 23, no. 2-3, pp. 83–104, 2012.
2. D. Spath et.al., „Potenziale der Mensch-Technik Interaktion für die effiziente und vernetzte Produktion von morgen", Studie des Fraunhofer IAO, Fraunhofer Verlag, 2013.
3. ISO 9241-420, „Ergonomics of human-system interaction -- Part 420: Selection of physical input devices", 2011.
4. D. Zühlke, „Nutzergerechte Entwicklung von Mensch-Maschine-Systemen – Useware-Entwicklung für technische Systeme", Springer, 2012.
5. L. Krauss, „Entwicklung und Evaluation einer Methodik zur Untersuchung von Interaktionsgeräten für Maschinen- und Prozessbediensysteme mit grafischen Benutungsoberflächen", Fortschritt-Bericht pak, Bd. 17, Kaiserslautern, 2003.

Virtual commissioning of cyber physical systems – a case study

Peter Eichinger, Bernhard Höfig, Alexander Schmidt

Hochschule Aalen - Technik und Wirtschaft
Beethovenstraße 1
73430 Aalen
Germany

Abstract. In this paper, we discuss the concept for virtual commissioning of a production system. Based on modules of the cyber physical factory of Festo GmbH the process simulation is built up using the Mechatronic Concept Designer of SIEMENS PLM. It is shown, how different simulation approaches can support the design and development process, both for mechanical hardware and process control software. The model of the system can be used for efficient testing and optimization of the automation code and helps to reduce the time for commissioning.

Keywords: virtual commissioning, digital twin, process control simulation

1 Motivation

The dynamic changes, which takes place in the field of IoT and automation opens new ways for the development and commissioning of production systems and factories. In order to face the challenges of a highly flexible production for individualized products down to lot size one and shorter product lifecycles, we need to develop and implement new development processes based on modern simulation techniques. For the design of complex cyber physical systems, the virtual representation, often called as "Digital Twin", is an essential cornerstone in order to setup a technically mature production system.

The ultimate goal is to build a digital twin which behaves like the real object and which can be tested and optimized in an early stage of the development process. In this paper, we will discuss some aspects and concepts for the setup of a digital twin based on modules of the cyber physical factory by Festo Didactic GmbH & Co. KG. We will show, how a virtual representation of this system can be used to design and optimize the control system for the production process and helps to reduce development time and errors in the commissioning process.

2 Application Example

The cyber physical factory (CP Factory) by Festo Didactic GmbH & Co. KG is a comprehensive, modular and expandable factory model for Industry 4.0, that demonstrates digital production. It is designed as teaching environment for the vocational training and shows the interaction of production line, human and product. With this setup, students and teachers can train the basic concepts and tools for a modern plant setup in the context of IoT and Industry 4.0 [1].

At the university of Aalen, we have a showroom for Industry 4.0, where we can use some modules of Festo's CP Factory. The application shows the process for workpieces which are stored in kind of shells and are transported on a workpiece holder. They can be ordered individually at a HMI-terminal. Three modules in the form of a magazin, a drilling-station and a turning-station process the order.

3 Results and Future Work

The digital twin has been implemented with Siemens NX software, especially the application Mechatronics Concept Designer MCD [2]. The simulation environment of the MCD is based on an AMD bullet physics engine.

The 3D CAD assembly is loaded to MCD and all relevant parts are set as rigid bodies. Surfaces of parts that theoretically can hit other parts are specified as collision bodies. In case of a collision, a contact force is calculated by the physics engine so that these two bodies affect each other in their movements. Nearly all movements are based on joints, driven by actors in kind of so-called „Speed Controls“ and „Position Controls“. Several sensors complete the automation. They check the end positions of each joint and actor or survey the workpiece.

All motion sequences of the system are tested and validated in a time- and event-based sequence diagram. This first skeletal structure allows a first visual illustration of the digital twin. Collisions during motions can be detected easy and early in the engineering process without a need of a real prototype.

The future work is to build up a connection to a real or simulated programmable logic controller (PLC). The goal is to simulate the behavior of actors and sensors and their interaction with a PLC. This step completes the virtual commissioning of the CP-Factory. It enables virtual acceptance tests of the real control system using the simulated CP-Factory under various scenarios.

In summary, the early development of a machine or production system can be supported by various tests of the code on a real PLC without any danger of damaging humans or the real machine by incorrect implementation.

References

1. Lernfabrik 4.0, Qualifikation für die Produktion der Zukunft, Festo Diadactic. http://www.festo-didactic.com/ov3/media/customers/1100/dsi_lernfabrik_4_0.pdf [Zugriff am 29.07.2016]
2. SIEMENS PLM Mechatronics Design https://www.plm.automation.siemens.com/en_us/products/nx/for-design/mechatronics-design/ [Zugriff am 29.07.2016]

A Holistic Model Based System Engineering Approach by Horizontally Integrated Domain Specific Models

Andreas Gallasch

Software Factory, Parkring 4, 85748 Garching n. Munich
gallasch@sf.com

Abstract. An increasing usage of software in manufacturing systems offers new opportunities for building closed loop control mechanisms. These could be human centric as well as fully automated. For both a significant more in software is required. The main challenge in using more software is the growth in complexity. Beside structural measures like modularization and standardization new approaches based on simultaneous and collaborative engineering could help managing this complexity. Today's tool infrastructure is typically optimized along enterprise functionalities. An increase in collaboration and usage of engineering information of different domains need a horizontally integrated infrastructure based on vertically integrated domain specific models. This article gives an overview from high level Model Based Systems Engineering over specific CAD and software models down to verification and validation on system level.

Keywords: Model Based Systems Engineering · Requirements Engineering · Test Management · Product Structure Management · Model Based Definition · Model Based Software Design · IoT Platforms · System Level Simulation · Machine Learning

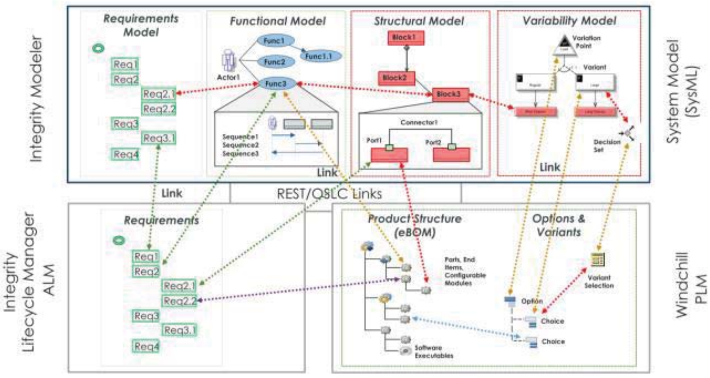
1 Introduction

German engineering and plant construction still has a strong position in the world market. In order to maintain and strengthen this position in the face of emerging competitors, companies are increasingly demanding to continually develop their product portfolio through innovation [1]. Today, product creation processes are generally based on documents. Such a document-oriented approach offers the advantages of a synchronized, step-by-step development. A collaborative approach based on a single source of information with more agility cannot be realized on such a basis. Innovative organizational forms, processes, methods and IT solutions are required that allow a model-based approach [2].

2 Horizontally Integrated Domain Models

A combined concept from Model Based Systems Engineering, extended by Product Line Engineering for modelling variability [3] [8], product lifecycle management and application lifecycle management [4] (Fig. 1) in addition with Model Based Software Design and System Level Simulation offers the possibility of such a collaborative approach. Model Based Systems Engineering (MBSE) is a multidisciplinary approach designed to develop a balanced system solution in response to diverse stakeholder needs [4]. The functional design is chosen as the common basis for the modeling. The description language is SysML with the profile SysML4Mechatronics [9]. It provides a relatively easy-to-understand and easy-to-carry display mode [5] [6].

Fig. 1. Horizontally Integrated Domain Models



References

1. Drescher, B, Klein, Th, Stich, P, Reinhart, G: Kontextspezifische Auswahl und Adaption von Entwicklungsvorgehen zur Effizienzsteigerung im Maschinen und Anlagenbau (W), in: Maurer, M. und Schulze, S.O. (Hrsg.): Tag des Systems Engineering: Zusammenhänge erkennen und gestalten, S. 53-65. Carl-Hanser-Verlag, München (2013)
2. Anderl, R; Eigner, M; Sendler, U; Stark, R: Smart Engineering – Interdisziplinäre Produktentstehung, in: acatech DISKUSSION. Springer Verlag, Heidelberg (2012)
3. Korf, A: Implementing ISO 26550:2013 Model Based, in: Complex Systems Design & Management: Proceedings of the Fifth International Conference on Complex Systems Design & Management CSD&M 2014. Springer Verlag, München (2014)
4. Gallasch, A.; Schmidt, R.; Leiprecht, J.; Müller, T.: Model Based Systems Engineering und PLM, warum und wie dies bei der Entwicklung von Maschinen zusammengehört, in Schulze, S.O.; Muggeo, C. (Hrsg.): Tag des Systems Engineering, S. 269-278. Carl-Hanser-Verlag, München (2015)
5. Friedenthal, S; Steiner, R; Moore, A: A Practical Guide to SysML - The Systems Modeling Language. Morgan Kaufmann Pub, San Francisco (2009)
6. Delligatti, L: SysML Distilled: a brief guide to the systems nodeling language. Addison-Wesley, Upper Saddle River NJ L (2014)
7. Alt, O: Modellbasierte Systementwicklung mit SysML. Carl-Hanser-Verlag, München (2012)
8. Pohl, K.; Böckle, G; van der Linden, F.J.: Software product line engineering: foundations, principles and techniques. Springer Verlag, Berlin Heidelberg (2005)
9. Kernschmidt, K.; Vogel-Heuser, B.: An interdisciplinary SysML based modelling approach for analysing change influences in production plants to support the engineering. In 2013 IEEE International Conference on Automation Science and Engineering (CASE), S. 1113-1118. doi:10.1109/CoASE.2013.6654030, (2013)

Smart Manufacturing in the Digital Factory – a Practical Case Study of an Industrie 4.0 Implementation

Corinna Engelhardt-Nowitzki[1], Mohamed Aburaia[1] and Erich Markl[1]
[1] UAS Technikum Wien, Department of Advanced Engineering Technologies, Höchstädtplatz 6, 1200 Vienna, Austria
{Corinna.Engelhardt, Mohamed.Aburaia, Erich.Markl}@technikum-wien.at

Abstract. In the course of proceeding factory digitization, industrial automation and robotics are subject to enormous, mainly software-driven changes. High competitive pressure enforces extensive manufacturing flexibility. Hence, advanced automation concepts and software architectures are to achieve an integrated data flow between heterogeneous production machinery. The aim is to implement a seamless production workflow that is reliable, fast, cost-efficient and flexible at the same time. At Eurocast 2017 a pilot factory will be presented that has implemented respective technologic concepts in a realistic production setup at the UAS Technikum Wien "Digital Factory": Several robotic systems from different manufacturers, with variable kinematic mechanisms, diverse control structures and from multiple technology generations compile a factory workflow, based on IoT approaches.

1 The UAS Technikum Wien "Digital Factory"

Recent advances in automation and robotics are highly influencing the development of efficient, resource-conserving and versatile production systems. Driving power is the demand for user-friendly, environmentally compatible, at the same time powerful and robust, flexible and adaptive, but yet cost-efficient manufacturing systems. In close cooperation with leading international technology manufacturers in the field of industrial automation and robotics, the University of Applied Sciences (UAS) Technikum Wien has developed a unique teaching and research landscape for industry 4.0 – referred to as "Digital Factory" (DF). The major enabler for this innovative manufacturing environment is the digitization of plants, machines, tools, work-pieces, products and product components. On the one hand innovative automation and robotics solutions combine mechanical engineering expertise with highly developed sensor concepts and powerful algorithms. E.g., transportation tasks are executed by mobile robot systems that autonomously navigate within the factory area. On the other hand, also less up-to-date robots and programmable controllers have been integrated into the Digital Factory. This represents a realistic production system, as it could be found in a typical Austrian company, in particular small or medium enterprises (SME). The networking and communication of the DF system elements is based on a broad variety of sensors, being integrated through internet communication and the subsequent exploitation of the data, thus obtained. Thereby, the Digital Factory enables a wide range of technical concepts and business models.

2 Product Concept and Production Workflow

The technical setting includes eight industrial robots and three mobile robots, integrating eight different manufacturers. The exemplary product to be manufactured is an axle-bearing end collar. The workflow is designed logistically suboptimal to represent typical industry settings. Each robot carries out a specific production task, and can be adjusted to execute different tasks through rapid tool change. Autonomous transport vehicles are using a wide range of methods (e.g., hodometry, indoor-GPS navigation) to perform make-to-stock, make-to-order (etc.) strategies.

3 Implementing Industrie 4.0 by Means of Advanced Automation

The UAS Technikum Wien Digital Factory exemplifies several typical Industry 4.0 settings, in particular inter-robot communication (e.g., SMC assembly station being loaded by a Wittman gantry robot and being served by a Festo mobile robot), intelligent routing (e.g., deciding between two molding stations), and the integration of additive manufacturing techniques. The DF is used as a training lab within several master and bachelor programs, e.g., for semester projects, lab sessions und degree thesis preparation. Research projects cover topics, such as integrated machine safety and IT-security or collaborative robotics based in vision techniques and sensor fusion. Innovation matters are especially:

- Advanced Automation: Smart Manufacturing in the digital factory, control and regulation of mechatronic systems
- Innovative sensor concepts: imaging sensors, intelligent sensors, multimodal sensor networks and sensor fusion
- Robotics: Selected questions of industrial, mobile and service robotics, Collaborative Robotics, Intelligent Industrial Work Assistants, Cognitive Robotics and Human Machine Interface
- Industrial Operations Management: business models, ontologies and architectural models for the DF, integrated simulation, control, and optimization of processes.

Acknowledgments. We thank our sponsors for their support, in particular ABB, Festo, Kuka, Siemens, SMC and Wittmann.

References

1. Brettel, M., Klein, M., Friederichsen, N.: The Relevance of Manufacturing Flexibility in the Context of Industrie 4.0. In: Procedia CIRP, 41 (2016) 105-110
2. Shariatzadeh, N., Lundholm, T., Lindberg, L., Sivard, G.: Integration of Digital Factory with Smart Factory Based on Internet of Things. In: Procedia CIRP, 50 (2016) 512-517
3. Prinz, C., Morlock, F. Freith, S., Kreggenfeld, N., Kreimeier, D., Kuhlenkötte, B.: Learning Factory Modules for Smart Factories. In: Procedia CIRP, 54 (2016) 113-118
4. Zülch, G., Stohwasser, S.: The Digital Factory: An Instrument of the present and the future. In: Computers in Industry 56/4 (2005), 323-324

Recent advances in adaptive sequential Monte Carlo methods

Víctor Elvira⋆, Joaquín Míguez†, and Petar M. Djurić♯
⋆ Communication Systems Dept., Télécom Lille (Institut Mines-Télécom), CRIStAL (CNRS), Villaneuve d'Ascq 59650 (France)
Email: victor.elvira@telecom-lille.fr
† Dept. of Signal Theory and Communications, Universidad Carlos III de Madrid, Leganés 28911 (Spain)
♯ Dept. of Electrical and Computer Eng., Stony Brook University, Stony Brook, NY 11794 (USA)

Extended Abstract

Many systems of different scientific areas are described through a statistical model that relates observed data to an unobserved state that evolves over the time. The interest is usually in learning sequentially about the unknown state from the observed data. Bayesian inference is a generic statistical framework that allows for dealing with uncertainty in a systematic way. In the sequential Bayesian inference problem, the data are processed to provide a probabilistic inference of the current hidden state, instead of just a pointwise estimation. Therefore, the interest is in computing the posterior distribution of the current state $\mathbf{x}_t$ at time t, conditioned to all the observed data $\mathbf{y}_{1:t} \equiv \{\mathbf{y}_1, \mathbf{y}_2, ..., \mathbf{y}_t\}$, i.e. obtaining the filtering distribution $p(\mathbf{x}_t|\mathbf{y}_{1:t})$. Unfortunately, exact inference is only possible in a small number of simplistic models, e.g. the linear Gaussian state-space model where $p(\mathbf{x}_t|\mathbf{y}_{1:t})$ is computed using the Kalman filter [1].

Sequential Monte Carlo (SMC) methods, also known as particle filters (PFs), allow for the approximation of the filtering distribution $p(\mathbf{x}_t|\mathbf{y}_{1:t})$ with the random measure $\hat{p}^N(\mathbf{x}_t|\mathbf{y}_{1:t})$, i.e.

$$p(\mathbf{x}_t|\mathbf{y}_{1:t}) \approx \hat{p}^N(\mathbf{x}_t|\mathbf{y}_{1:t}) = \sum_{n=1}^{N} \bar{w}_n \mathbf{x}_t^{(n)},$$

where $\{\mathbf{x}_t^{(n)}\}_{n=1}^N$ is the set of N particles (or random samples) and $\{\bar{w}_n\}_{n=1}^N$ is the set of associated weights [2]. The weights are normalized, i.e. $\sum_{j=1}^N \bar{w}_j = 1$. The rate of convergence of the approximate probability distribution towards the true posterior is inversely proportional to $\sqrt{N}$ [3], i.e., the filter "perfectly" approximates the posterior distribution when the number of particles tends to infinity. However, the computational load of the particle filter grows with the number of particles. Hence, practitioners must choose a specific N in the design of their filters. In practice, N is usually chosen heuristically according to the experience of the practitioner. The choice of the number of particles is a delicate subject because the mismatch between $p(\mathbf{x}_t|\mathbf{y}_{1:t})$ and the approximation $\hat{p}^N(\mathbf{x}_t|\mathbf{y}_{1:t})$ is model-dependent and obviously also unknown. Then, there is a clear trade-off between performance and computational complexity, but this relation is not straightforward; e.g. increasing N over a certain value may not significantly reduce the mismatch of the approximation, while decreasing N below some other value can dramatically affect the performance of the filter.

In this paper, we present an overview of recent advances in SMC methods for adapting the number of particles in a dynamic way, and we propose a framework that allows for creating novel algorithms that are more efficient. The adaptation of the number of particles is closely related to the problem of online assessment of the filter convergence. In the wide literature, few works have addressed this topic, and most of them rely on heuristic rules or unrealistic assumptions. In [4], the number of particles is selected so that a bound on the approximation error does not exceed a threshold with certain probability. In [5], an adaptation of the number of particles is proposed, based on the KLD approach of [4]. In [6], the adaptation of the number of particles is based on the effective sample size, which has been recently shown to be a poor measure [7]. In other scenarios, several candidate models are possible, and different inference methods can be used for allocating the number of particles in different parallel filters [8, 9]. Recently, we have proposed a methodology for assessing the convergence of the PF and consequently adapting the number of samples [10]. This methodology is supported with a solid theory, and different algorithms have been recently proposed [10][11]. All these algorithms allow for an automatic selection of the number of particles, at the price of having to pre-select few new parameters. These parameters have physical meaning and allow the practitioner to select the desired operation point by considering performance-computational cost trade-offs. In this paper, we investigate an appropriate choice of the parameters of the different algorithms in a new framework, and we propose a novel technique for adapting the parameters of the algorithms in an online manner. We provide numerical simulations in non-linear state-space models, and we compare the different algorithms.

References

1. R. E. Kalman, "A new approach to linear filtering and prediction problems," *Journal of Basic Engineering*, vol. 82, pp. 35–45, 1960.
2. P. M. Djurić, J. H. Kotecha, J. Zhang, Y. Huang, T. Ghirmai, M. F. Bugallo, and J. Míguez, "Particle filtering," *IEEE Signal Processing Magazine*, vol. 20, no. 5, pp. 19–38, September 2003.
3. P. Del Moral and L. Miclo, "Branching and interacting particle systems. Approximations of Feynman-Kac formulae with applications to non-linear filtering," *Lecture Notes in Mathematics*, pp. 1–145, 2000.
4. D. Fox, "Adapting the sample size in particle filters through KLD-sampling," *The International Journal of Robotics Research*, vol. 22, no. 12, pp. 985–1003, 2003.
5. A. Soto, "Self adaptive particle filter," in *IJCAI*, 2005, pp. 1398–1406.
6. O. Straka and M. Šimandl, "Particle filter adaptation based on efficient sample size," in *14th IFAC Symposium on System Identification*, 2006.
7. L. Martino, V. Elvira, and F. Louzada, "Effective sample size for is based on discrepancy measures," *Signal Processing*, vol. 131, pp. 386 – 401, 2017.

8. I. Urteaga, M. F Bugallo, and P. M. Djurić, "Sequential monte carlo methods under model uncertainty," in *Statistical Signal Processing Workshop (SSP), 2016 IEEE*. IEEE, 2016, pp. 1–5.
9. L. Martino, J. Read, V. Elvira, and F. Louzada, "Cooperative parallel particle filters for on-line model selection and applications to urban mobility," *Digital Signal Processing*, vol. 60, pp. 172–185, 2017.
10. V. Elvira, J. Míguez, and P.M. Djurić, "Adapting the number of particles in sequential monte carlo methods through an online scheme for convergence assessment," *to appear in IEEE Transactions on Signal Processing, arXiv:1509.04879*, 2017.
11. V. Elvira, J. Míguez, and P.M. Djurić, "A novel algorithm for adapting the number of particles in particle filtering," in *Sensor Array and Multichannel Signal Processing Workshop (SAM), 2016 IEEE*. IEEE, 2016, pp. 1–5.

Direction of Arrival Estimation using Compressed Sensing

Philipp Zagar
Vienna Technical University, Karlsplatz 13, 1040 Wien, Austria,
Institute of Telecommunications
philipp_zagar@hotmail.com,
home page: `https://www.nt.tuwien.ac.at/`

Abstract. A localization method for moving RFID[1]–readers via passive RFID-tags was investigated. Within this publication the subproblem of estimating the direction of arrival (DOA) of backscattered electromagnetic waves is worked out. Therefore, a method called compressive beamforming is compared to the well–known Multiple Signal Classification (MUSIC) algorithm. It was shown that this method is suitable for direction of arrival estimation. As it can utilize single–snapshots to estimate DOA it is assumed that it might be better suitable in real time applications than the MUSIC–algorithm.

keywords: direction of arrival estimation, RFID, compressed sensing, MUSIC, compressive beamforming

1. Problem Definition and Results

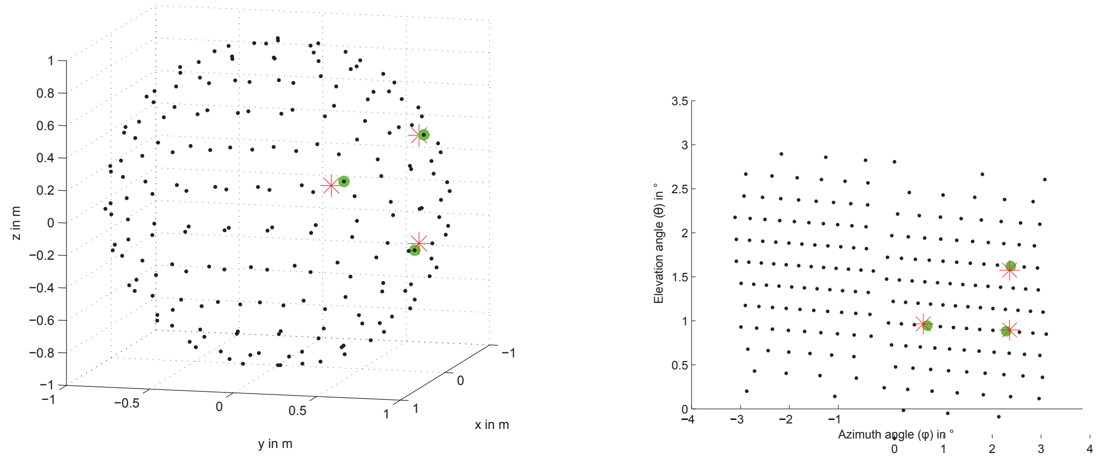
In my work possible ways for estimating the time–sequence of positions, or trajectory, of a moving RFID–reader using passive RFID–tags positioned at known locations in space as waypoints was investigated. Such systems are mainly used for indoor environments where devices that rely on the availability of the Global Positioning System (GPS) do not work properly. Possible applications that demand for indoor positioning systems are for example the tracking of mobile robots or humans or automatic transport systems in the logistics chain of a production line.

In this contribution the subproblem of estimating the direction of arrival (DOA) of the backscattered electromagnetic waves from the passive RFID–tags is considered. Therefore, compressive beamforming [1] is compared to the well–known method of Multiple Signal Classification (MUSIC) algorithm.

The idea conveyed in this paper is to apply a so–called compressed sensing method to the DOA–estimation problem by utilizing the sparse nature of the directions of arrival of the backscattered electromagnetic waves. This leads to a non–convex minimization problem[2] $\min_{\vec{z}} \|\vec{z}\|_0 \quad \text{subject to} \quad \vec{y} = A_c\vec{z}$ which can be approximated to find out the true DOA [1]. The minimization problem is analyzed and it is suggested a way to approximate it by introducing a combined merit–function as it is used in the so–called least absolute shrinkage and selection

[1] radio frequency identification

[2] $\|\cdot\|_0$ is the operator which gives back the number of non–zero components of the vector it is operating on.



(a) Endpoints of 200 possible steering vectors (black), the 3 steering vectors that were estimated to correspond with the true directions of arrival (green) and the steering vectors in the true directions of arrival $\vec{a}(\varphi_i, \theta_i)$ with $i \in \{1, 2, 3\}$.

(b) Azimuth and elevation angles (φ, θ) that were used to create the dictionary matrix (black), true directions of arrival parameterized by (φ, θ) and estimated parameter values (green).

Figure 1: Result of the estimation of the three directions of arrival (φ_i, θ_i) with $i \in \{1, 2, 3\}$.

operator (LASSO)–algorithm, mainly applied in regression analysis. Figure 1 shows an example of a successful DOA–estimation by applying this method. In the full paper a closer look is taken at the so–called dictionary matrix A_c and it is shown how its column vectors influence the DOA estimation quality. The LASSO–algorithm is compared to the estimation using the MUSIC–algorithm and the computational complexity of those algorithms is briefly discussed.

2. References

[1] Gerstoft P., Xenaki A., C. F. Mecklenbräuker, Multiple and single snapshot compressive beamforming, in: Journal of the Acoustical Society of America, Vol. 138, No. 4, pp. 2003, 2015.

Acknowlegement

This work has been carried out at the Vienna University of Technology, Institute of Telecommunications. It has been funded by the Christian Doppler Laboratory for Wireless Technologies for Sustainable Mobility and its industrial partner Infineon Technologies. The financial support by the Federal Ministry of Economy, Family and Youth and the National Foundation for Research, Technology and Development is gratefully acknowledged. Furthermore, I am grateful to Prof. Markus Rupp for his supervision and the fruitful discussions.

Investigations on Sparse System Identification with l_0-LMS, Zero-Attracting LMS and Linearized Bregman Iterations

Andreas Gebhard, Michael Lunglmayr, and Mario Huemer

Johannes Kepler University Linz, Institute of Signal Processing,
Altenberger Strasse. 69, 4040 Linz, Austria
{andreas.gebhard, michael.lunglmayr, mario.huemer}@jku.at

In many applications such as interference cancellation or system identification, the underlying system impulse response is of sparse nature. In the presence of noise, the zero-elements cannot exactly be identified by a minimization of the l_2-norm or related algorithms such as the traditional least-mean-square (LMS) algorithm. Extensions to the LMS algorithm such as the Zero-Attracting Least-Mean Square (ZA-LMS), l_0-Least-Mean Square (l_0-LMS) or the recently proposed Fast Linearized Bregman (FLB) algorithm all show significantly better performance in terms of steady state mean-square-error (MSE). The ZA-LMS and l_0-LMS comprise a zero-point attracting function in the coefficient update which causes a biased estimation [2, 3]. This can e.g. be seen in the coefficient update of the ZA-LMS:

$$e_{\mathrm{ZA}}[n] = d[n] - \mathbf{x}[n]^T \hat{\mathbf{w}}_{\mathrm{ZA}}[n] \tag{1}$$

$$\hat{\mathbf{w}}_{\mathrm{ZA}}[n+1] = \hat{\mathbf{w}}_{\mathrm{ZA}}[n] + \mu e_{\mathrm{ZA}}[n]\mathbf{x}[n] - \lambda_{\mathrm{ZA}} \operatorname{sign}(\hat{\mathbf{w}}_{\mathrm{ZA}}[n]) \tag{2}$$

where $d[n]$ is the desired signal, $x[n]$ the training signal, and $\hat{\mathbf{w}}_{\mathrm{ZA}}[n]$ the coefficient estimate.

In the FLB algorithm [2, 4]:

$$\mathbf{u}[n] = \big(u_i[n]\big)_i \text{ with } u_i[n] = \max\left(|\hat{w}_{\mathrm{FLB},i}| - \lambda_{\mathrm{FLB}}, 0\right) \operatorname{sign}\left(\hat{w}_{\mathrm{FLB},i}\right) \tag{3}$$

$$e_{\mathrm{FLB}}[n] = d[n] - \mathbf{x}[n]^T \mathbf{u}[n] \tag{4}$$

$$\hat{\mathbf{w}}_{\mathrm{FLB}}[n+1] = \hat{\mathbf{w}}_{\mathrm{FLB}}[n] + \mu e_{\mathrm{FLB}}[n]\mathbf{x}[n] \tag{5}$$

a sparsity promoting regularizer is used as described by (3), which maintains the unbiasedness of the estimate [2]. The threshold parameter λ_{FLB} is a tradeoff between achieving sparse solutions and fast convergence of the adaptive filter. Choosing a small value results in a fast convergence but also leads to more non-zero elements in the solution and vice versa.

In this contribution we compare the mentioned algorithms in terms of transient and steady-state performance for different signal-to-noise ratio (SNR) scenarios. We will discuss the tradeoff between a fast convergence and a high sparsity in the result. We will show performance results and present improvement strategies for the FLB based algorithms incorporating fast convergence as well as high sparsity of the result. An exemplary result, evaluating the sparsity in terms of the number of non-zero elements is shown in Fig. 1. It demonstrates a drawback of the l_0-LMS as well as the ZA-LMS: the elements of the estimated vectors never become exactly zero, while the sparsity promoting regularizer of the FLB based algorithms set elements exactly to zero. We furthermore investigate the behavior of the algorithms in case a fractional delay is introduced between the desired signal $d[n]$ and the training signal $x[n]$.

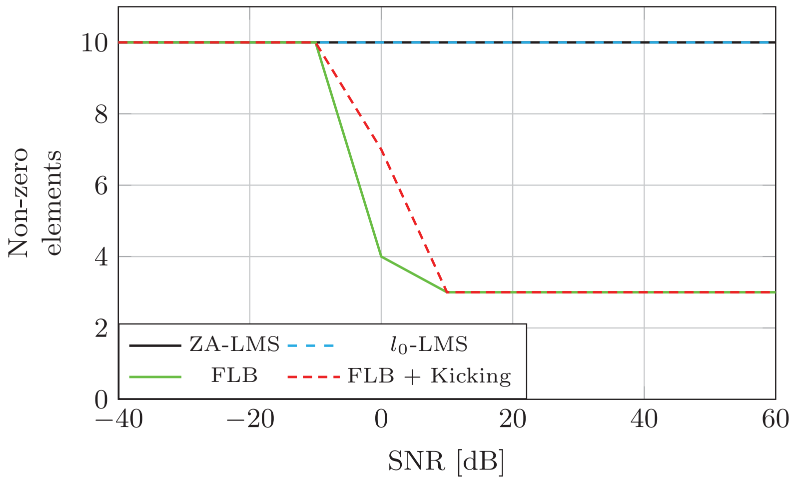


Fig. 1. Number of non-zero elements in $\hat{\mathbf{w}}$ after 1000 iterations. The true impulse response has 3 non-zero elements.

ACKNOWLEDGMENT: This work has been partly funded by the Linz Center of Mechatronics (LCM) GmbH as part of a K2 project. K2 projects are financed using funding from the Austrian COMET K2 programme. The COMET K2 projects at LCM are supported by the Austrian federal government, the federal state of Upper Austria, the Johannes Kepler University and all of the scientific partners which form the COMET K2 consortium.

References

1. Chen, Y., Gu, Y., Hero, A. O.: Sparse LMS for system identification. In: IEEE International Conference on Acoustics, Speech and Signal Processing, (2009)
2. Hu, T., Chklovskii, D. B.: Sparse LMS via online linearized Bregman iteration. In: IEEE International Conference on Acoustics, Speech and Signal Processing, (2014)
3. Chen, J., Richard, C., Song, Y., Brie, D.: Transient Performance Analysis of Zero-Attracting LMS, In: IEEE Signal Processing Letters, (2016)
4. Lunglmayr, M., Huemer, M.: Efficient Linearized Bregman Iteration for Sparse Adaptive Filters and Kaczmarz Solvers. In: IEEE Sensor Array and Multichannel Signal Processing Workshop, Rio de Janeiro (2016)

Investigation of Finger Gesture Recognition Algorithms for Capacitive Proximity Sensing

Leonhard Haslinger, Simon Hehenberger, and Bernhard G. Zagar

Johannes Kepler University Linz, Institute for Measurement Technology, Altenberger Straße 69, 4040 Linz, Austria
{leonhard.haslinger,simon.hehenberger,bernhard.zagar}@jku.at
http://www.jku.at/emt

Abstract. This contribution presents a comparison of different algorithms for finger gesture recognition in the context of capacitive proximity sensing. The processing of the measured data for gesture interpretation can be done directly with the capacitance values or via a preprocessing step to get more meaningful parameters like position and velocity. For this signal processing application a newly developed measurement hardware is used.

Keywords: capacitive proximity sensing, 3D position estimation, human-machine interaction, machine learning strategies

1 Introduction

The target of this work is the investigation of different algorithms for finger gesture recognition in the context of capacitive proximity sensing. Here, wipe gestures (e. g., up and down, left and right, circular forms, etc.) as known from interaction with smartphones are recognized as user intentions. Figure 1 shows a schematic of the measurement set-up with a sensing and a shielding electrode as well as an interacting human finger, where the coordinates x_m, y_m and z_m describe the center position of its tip. The output signal of an astable multivibrator whos frequency determining capacity is C_3D excites the sensing electrode. With a guard amplifier the shielding electrode is applied to the same potential as the sensing electrode. Thereby, the effect or influence of parasitic capacitances is minimized. The touchless user interface used is a newly developed hardware with eight capacitance measurement channels each connected to an electrode which is part of an array. The concept for this measurement hardware is based on [1] where the multi-electrode structure can be seen as a superposition of the set-up in Fig 1.

2 Methods

The processing of the measured data for gesture interpretation can be done directly with the capacitance values or via a preprocessing step to get more meaningful parameters like position and velocity. In the direct processing case a higher temporal resolution of the measurement system is necessary as when resorting to a preprocessing step. Here, rapid changes of the signal must be recorded in detail because mainly statistical methods are used to recognize and distinguish different gestures. Another approach is a two step gesture recognition. In a first step with a spatially dependent capacitance model for C_3D (see

[2]) the finger position is estimated through a nonlinear optimization problem in [3]. The challenge is to execute all calculations within the time needed to measure capacitance. The trajectory and the velocity for recorded finger motions are illustrated in Fig. 2. With this data it is easier to find features for the characterisation of finger gestures. Furthermore, predictions for future positions are possible, and thus less temporal resolution is shown to be sufficient for the capacitance measurement concerning gesture recognition.

3 Conclusion

For both the presented signal processing concepts machine learning algorithms (e. g., support vector machines) can be utilised. In the context of direct processing, a rapid measurement and evaluation scheme is required, and therefore only moderate results were obtained in initial tests. Proof of concept studies showed that a cascade structure, which includes a preprocessing step for data preparation, is a more promising method. Here, machine learning algorithms were used in a second stage to recognize finger gestures. Instead of these algorithms Fourier descriptors and shape numbers known from image processing [4] can be potential candidates for gesture recognition in further studies.

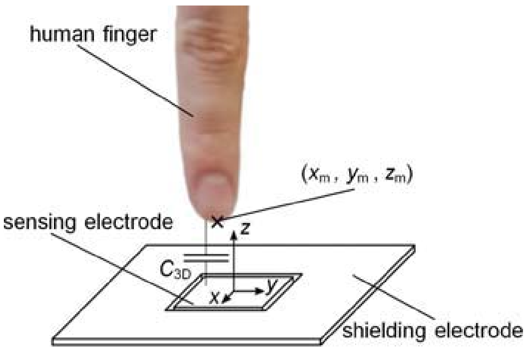


Fig. 1. Schematic of the set-up.

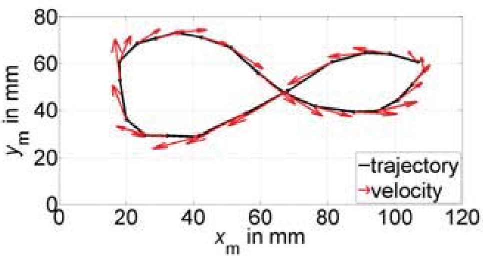


Fig. 2. Recorded finger motions.

Acknowledgements

The authors gratefully acknowledge the partial financial support for the work presented in this paper by the Austrian Research Promotion Agency (FFG) under contract grant 846057 and WimTec Sanitärprodukte GmbH.

References

1. Haslinger, L., Hehenberger, S., Zagar, B. G.: Capacitance System for Touchless Interaction. In: Proceedings Eurosensor 2016, pp. 1071–1074, Budapest.
2. Haslinger, L., Zagar, B. G.: Voruntersuchung zur berührungslosen Gestenerkennung mittels kapazitiver Sensorik. In: AMA Service GmbH (Eds.): Tagungsband 18. GMA/ITG-Fachtagung: Sensoren und Messsysteme 2016, pp. 210–217, Nürnberg.
3. Haslinger, L., Zagar, B. G.: 3D Position Estimation with Capacitive Sensors for Touchless Interaction. In: Proceedings of the 2nd International Conference on Sensors and Electronic Instrumentation Advances 2016, pp. 123–127, Barcelona.
4. Jain, A. K.: Fundamentals of Digital Image Processing. Prentice Hall, New Jersey (1989).

In–Line Signal Processing of Faraday–Magnetometer Scans

Johannes Egger and Bernhard G. Zagar

Johannes Kepler University, Institute for Measurement Technology, Linz, Austria
johannes.egger@jku.at, http://www.jku.at/emt/content

Keywords: Faraday magnetometer, Raspberry Pi, In–line processing

1 Introduction

We report on the signal processing of line-scan data associated with a Faraday— magnetometer to evaluate the production quality of magnetic coatings in a continuous roll–to–roll coating process of polyethylene foil. In order to accommodate a sufficient scan density the scan rate of the employed line–scan camera (Hamamatsu 128 pixel camera) needs to be in excess of 60 k line/s with a lateral resolution of the optical set–up being equal to the camera's resolution of 60μm per pixel (micro–optics with 1:1 magnification).

The sensing effect is the magneto–optical Faraday–effect [1] which rotates the polarization angle of incident linearly polarized light depending on the magnetic flux density along the path of light within a Faraday–crystal and is evaluated by an analyzing polarizer and projected onto the camera's face plate.

For certain processes subject to an obligate documentation all the measured data needs to be stored permanently and reliably in addition to being analyzed in real–time to quickly capture failures.

In this particular application, we report on the to be designed system needs to be able to stream continuously at a raw data rate of 8.192 MB per second for at least four hours a piece. On top of that the real–time signal processing algorithm needs to determine with very little delay a figure of merit of the current magnetic coating quality.

We define the coating quality as the mean squared deviation (Eqn. 1) from the mean (Eqn. 2) to be determined per scan line and stored in the data stream, too.

$$\sigma^2 = \frac{1}{N-1} \sum_{n=0}^{N-1} \left(I(n) - \overline{I} \right)^2 \tag{1}$$

$$\overline{I} = \frac{1}{N} \sum_{n=0}^{N-1} I(n) \tag{2}$$

We report on the hardware and software aspects of the system (depicted in Fig. 1 (left)) that is able to accommodate the sought after speed in processing the discretized data stream and show first results (depicted in Fig. 1 (right)).

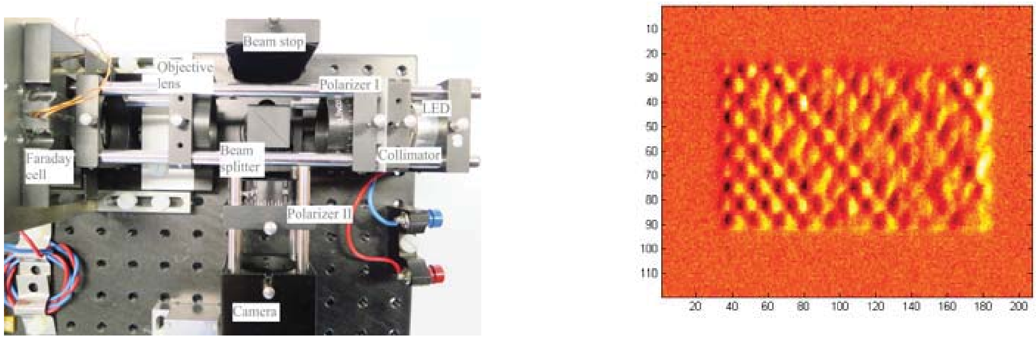


Fig. 1. Optical set–up of Faraday–System (left) and first scan results showing a magnetic pattern on a PET foil (right)

2 Signal Processing Schematic

We utilize a Hamamatsu camera (type S11106-10) with 128 square pixel. All control signals are provided by a CPLD (XC9572XL). To buffer the synchronized video signal to the asynchronous processing a 32 kB asynchronous FIFO (type IDT7207) is used. This FIFO is connected to a Raspberry Pi (1.2 GHz 64-bit quad-core ARMv8) CPU. The OS runs on 4.4.6 PREEMPT kernel. The overall schematic of the storage system can be seen in Fig. 2.

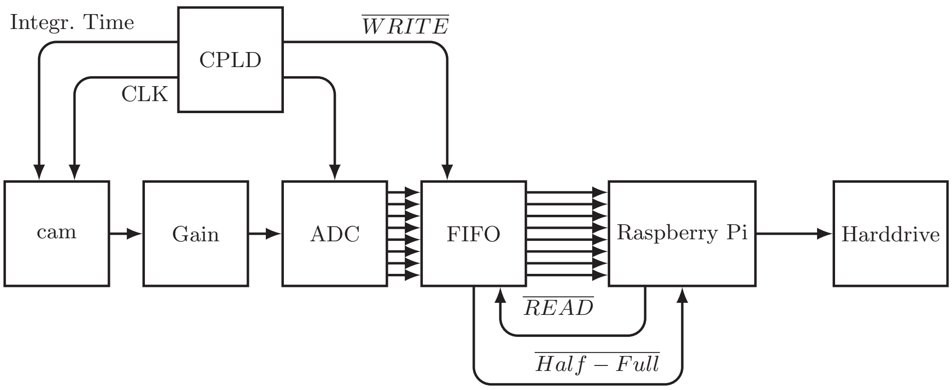


Fig. 2. Schematic of the control flow to store the data

References

1. M. von Ardenne, G. Mussiol, S. Reball, Effekte der Physik, Harri Deutsch, 1997
2. Raspberry Pi Foundation `https://www.raspberrypi.org/documentation/hardware/raspberrypi/README.md`

A back substitution method for a QR decomposition based Recursive Least Squares Algorithm

Markus Hoflehner[1], Roman Marŝálek[2] and Andreas Springer[1]

[1] Institute for Communications Engineering and RF-Systems,
Johannes Kepler University Linz, Austria
{markus.hoflehner,andreas.springer}@jku.at

[2] Department of Radio Electronics, Brno University of Technology, Czech Republic
marsaler@feec.vutbr.cz

Abstract. Keywords: digital predistotion, adaptive estimation, QR decomposition, recursive least squares, back substitution, systolic array

1 Introduction

To solve least squares problems a large variety of methods exist. One adaptive approach is the recursive least squares algorithm (RLS), or the QR decomposition based RLS (QR-RLS) which offers, a better numerical stability and an efficient implementation using a systolic array [1]. A major drawback however is the need for calculating multiple division and square roots for each update of the signal correlation matrix. Thus an optimized algorithm needs to overcome these problems in order to be hardware and energy efficient. One application for our new algorithm is digital predistortion in mobile devices.

In [2] a method for real valued signals omitting the division and square root operation was presented. However, to the best of our knowledge, no work on the extension to complex signals exists and even no systolic array implementation was proposed so far. In [3] we show a square root and division free QR-RLS including a systolic array implementation for complex signals. In the paper we expand the QR-RLS algorithm by introducing a back substitution algorithm that fits to the made modifications. The presented algorithm allows a chip space and energy efficient recursive lease squares solver in the form of an systolic array.

2 Implementation

The input of the QR-RLS algorithm are input samples $x[n]$ and output samples $y[n]$ of the system to be identified. The output are the model coefficients ($\boldsymbol{w}[n]$) of the identified model. Our algorithm is a two stage process, in the first stage we introduce the input samples into the triangular signal correlation matrix $\boldsymbol{\phi}$ and the vector $\boldsymbol{p}^H$. In the second stage we calculate our model coefficients ($\boldsymbol{w}[n]$) using the triangular matrix $\boldsymbol{\phi}$ and $\boldsymbol{p}^H$.

$$\boldsymbol{w}\,[n] = \boldsymbol{p}^H[n]\,\boldsymbol{\phi}^{-1}[n] \qquad (1)$$

In the first part, introducing input samples into $\boldsymbol{\phi}$ and $\boldsymbol{p}^H$ is done by using a series of Givens rotations. For this we need to calculate a sequence of $\frac{\phi_{i,i}}{\sqrt{x^2+|\phi_{i,i}|^2}}$ with every new sample. As shown in [2] the square root and division calculation needed in this rotation part can be bypassed by separating the values to rotate by: $\phi_{i,j} = \frac{r_{i,j}}{\sqrt{Z_i}}$. Here i denotes the column and j the row, it is noteworthy that there is only one Z_i for each column. For choosing $r_{i,j}$ and Z_i we have to consider the number format and bit width available in the hardware. In [3] we show the algorithm and a systolic array implementation for complex signals using the separation of $\phi_{i,j}$ into $r_{i,j}$ and Z_i. The output of this first stage is the triangular matrix $\boldsymbol{\phi}$ an the vector $\boldsymbol{p}^H$ which contain all the new information retrieved from the input signals ($x[n]$, $y[n]$). Additionally each element has the form $\frac{r_{i,j}}{\sqrt{Z_i}}$.

In the second step, we calculate the model coefficients by back substitution. Ordinarily it would be necessary to calculate $\phi_{i,j} = \frac{r_{i,j}}{\sqrt{Z_i}}$ before the back substitution. But considering the the separation into $r_{i,j}$ and Z_i, it can be shown that due to the choice of Z_i applying to each column of the matrix ϕ it cancels out in the back substitution. This results in only the $r_{i,j}$ part, which eliminates the need to calculate $\phi_{i,j} = \frac{r_{i,j}}{\sqrt{Z_i}}$. As a major advantage of our algorithm the division and square root calculation is removed in the back substitution algorithm. As an example, equation (1) is shown here for a model with two coefficients.

$$\begin{bmatrix} w_1 \ w_2 \end{bmatrix} = \begin{bmatrix} \frac{r_{p_1^H}}{\sqrt{Z_1}} & \frac{r_{p_2^H}}{\sqrt{Z_2}} \end{bmatrix} \cdot \begin{bmatrix} \frac{r_{\phi_{11}}}{\sqrt{Z_1}} & 0 \\ \frac{r_{\phi_{21}}}{\sqrt{Z_1}} & \frac{r_{\phi_{22}}}{\sqrt{Z_2}} \end{bmatrix}^{-1} \tag{2}$$

For example, calculating w_2 shows how $\sqrt{Z_2}$ is canceled out:

$$w_2 = \frac{\frac{r_{p_2^H}}{\sqrt{Z_2}}}{\frac{r_{\phi_{2,2}}}{\sqrt{Z_2}}} = \frac{r_{p_2^H}}{r_{\phi_{2,2}}} \tag{3}$$

In the final paper we will expand on the mathematical background and present the systolic array implementation for the back substitution part. Additionally we show the hardware efficient structure and explain the flow of the data from the triangular matrix $\boldsymbol{\phi}$ an the vector $\boldsymbol{p}^H$ to the back substitution stage.

References

1. Haykin, Simon: Adaptive Filter Theory (3rd Ed.) (1996)
2. J. Götze and U. Schwiegelshohn: A Square Root and Division Free Givens Rotation for Solving Least Squares Problems on Systolic Arrays. SIAM Journal on Scientific and Statistical Computing 12, 4, 800-807 (1991)
3. M. Hoflehner and A. Springer: A square root and division free QR-RLS algorithm for digital predistortion using a systolic array implementation, Manuscript in preparation

Influence of MEMS Microphones Imperfections on the Performance of First-Order Adaptive Differential Microphone Arrays

A. Gaich and M. Huemer

Institute of Signal Processing, Johannes Kepler University Linz.
andreas.gaich@jku.at

The performance of an acoustic beamformer is dependent upon a number of factors. Major issues are the number of microphones used, the target localization error, the microphone position error in the array and the microphone's amplitude and phase mismatch, denoted as microphone mismatch in the following, to all other microphones in the array. With regard to the last point, for an optimal performance the microphones used in the array have to be perfectly matched.

Micro-electro-mechanical systems (MEMS) microphones offer the advantage to be fabricated simultaneously as a single die providing a much better frequency response matching than conventional electret condenser microphones. Still, there is potential for further improvement for matching the MEMS microphones. The influence of the microphone mismatch is highly dependent on the used beamforming algorithm. A differential micophone array (DMA) enables a frequency independent beam pattern for small microphone array configurations with the drawback of an increased white noise gain (WNG). The WNG is a measure of the amplification of uncorrelated noise, i.e. sensor noise, thus indicating the robustness of a beamformer to microphone imperfections. To mitigate the WNG in DMAs the minimum-norm solution was proposed in [1].

In this work the performance of a first-order adaptive differential microphone array (FOADMA) is analyzed, when used in a speech enhancement application. Specifically, we investigate the impact of the number of used microphones, the microphone spacing, the microphone signal-to-noise ratio (SNR) and the microphone mismatch. An efficient implementation of the FOADMA, which is used in this work, was proposed in [2]. There the overall beamformer consists of two fixed beamformers realized as individual DMAs forming the so-called forward-facing cardioid $C_f(\omega, \theta)$ and the backward-facing cardioid $C_b(\omega, \theta)$. The outputs of these two are combined to obtain the overall output $Y(\omega, \theta)$, given in the frequency domain as

$$Y(\omega, \theta) = [C_f(\omega, \theta) - \beta C_b(\omega, \theta)]\, H_L(\omega), \tag{1}$$

where β is a real constant and $H_L(\omega)$ is the compensation filter.

Figure 1 shows the simulation results of the speech enhancement performance of a two-element FOADMA utilizing measured frequency responses of state-of-the-art MEMS microphones. A target speaker is simulated in front of the microphone array at 1m distance within a diffuse babble noise field with a signal-to-interference ratio of 3 dB. All results are averaged over 40 speakers from the GRID Corpus [3], and are depicted in terms of perceptual evaluation of speech quality (PESQ), an ITU recommendation for speech quality estimation, in dependence of the microphone SNR. Results are shown for perfect microphone matching on the left side, and for microphone mismatch on the right side. Details about the characterization of the mismatch will be provided in the long version of the paper. The unprocessed signal (UP) is the recording of just one microphone in the array and determines the baseline of the enhancement performance. The other curves show the results of the FOADMA for different microphone spacings. It can be clearly seen that the microphone mismatch degrades the speech enhancement performance. This effect is more distinct for smaller microphone spacing. In case of perfect matching and a spacing of $d = 1$mm a performance gain is achieved for microphone SNRs greater than 69 dB while larger spacings lead to a performance improvement over the entire investigated SNR range. Contrary, for the simulated microphone mismatch a performance gain is only obtained for a microphone spacing larger than or equal to 10 mm.

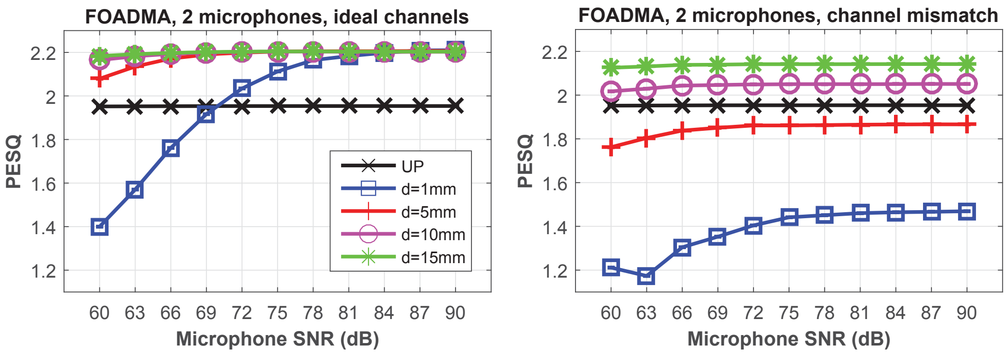


Fig. 1. Speech enhancement performance of FOADMAs for perfect microphone matching (left) and microphone mismatch (right).

In the final version of the paper the algorithm description, the simulation framework and the experimental setup will be described in detail. Furthermore, we will show much more results and will discuss them in great detail. Specifically other noise scenarios, such as low ambient noise and room reverberation will be treated. As an important outcome we will show that by the use of more than two microphones the speech enhancement performance becomes almost independent of the microphone mismatch.

References

1. J. Benesty and J. Chen, *Study and Design of Differential Microphone Arrays*, Springer-Verlag Berlin Heidelberg, Oct. 2012.
2. G. Elko and A. Pong, "A simple adaptive first-order differential microphone" In the *IEEE ASSP Workshop on Applications of Signal Processing to Audio and Acoustics*, pp. 169-172, Oct. 1995.
3. M. Cooke, J. Barker, S. Cunningham and X. Shao, "An audio-visual corpus for speech perception and automatic speech recognition", In *Acoustical Society of America Journal*, vol. 120, pp. 2421-2424, Nov. 2006.

Global Decision Making for Wavelet Based ECG Segmentation

Carl Böck[1], Michael Lunglmayr[1], Christoph Mahringer[1], Jens Meier[2], and Mario Huemer[1]

[1]Institute of Signal Processing, Johannes Kepler University Linz.
{carl.boeck}@jku.at
[2]Department of Anesthesiology and Critical Care Medicine, Kepler University Hospital Linz.

The electrocardiogram (ECG) is a well-established and easy to obtain physiological signal of remarkable diagnostic power. It is composed of the concatenation of single ECG beats, which themselves can be split into single waves (P,Q,R,S,T wave). Most of its clinically useful information is given by the amplitudes and durations of the single waves as well as the time intervals between them. Thus, automated ECG beat detection and the subsequent segmentation into the beats' waves has been an important subject of research during the past decades. Algorithms have to be capable of dealing with inter-individual morphology as well as common artifacts, characteristic for ECG recordings. Consequently, there exist many approaches for ECG beat segmentation. One of the most promising algorithms is based on the wavelet transform (WT) and was suggested by [1]. The method uses the stationary discrete wavelet transform (SDWT), and it can be decomposed into the steps shown in Figure 1. In this work we introduce an improvement of this approach, leading to an algorithm which is especially suited to detect minimal changes of the characteristic intervals and amplitudes in a patient's ECG over time.

As suggested in [1], first the SDWT for scales[1] $d_1 - d_4$ of the raw ECG is deter-

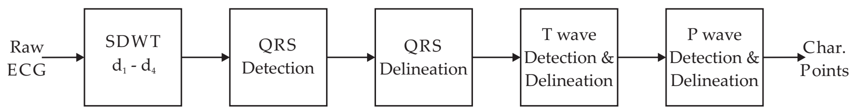


Fig. 1. Method used for extraction of ECG characteristic points.

mined, which enables to identify characteristic rising and falling edges as well as local extremes of the single ECG beats (Figure 2a). Based on this information, different valid morphologies can be distinguished, and subsequently onset, peak and end of the specific waves can be detected. Depending on which wave one is looking for, the information of the according scales $d_1 - d_4$ can be exploited, since the P and T waves have significant energy components in scales 3 and 4 (lower frequencies) while the Q and the S wave are mainly associated with scale 1 and 2 (higher frequencies). The R wave usually influences all scales. A crucial step for the detection of the correct onset, peak and end of a wave, is

[1] Scales of the WT correspond to frequency bands, whereby low scales represent high frequencies and high scales represent low frequencies.

the selection of the right significant minima and maxima of the according scales out of several potential candidates. As shown for the P wave in Figure 2b, there usually exist several maxima / minima (MM) candidates within a specific search window due to noise or other influences. In the work of [1] the decision which of the MM to select, is based on local amplitude criteria only, without performing any regularity analysis. That means, the selection of the MM only depends on the currently segmented beat. As shown in Figure 2b this may lead to a wrong detection of ECG characteristic points for the second and third beat.
In the final paper we suggest a method based on using global information rather than only local information for decision making. For that reason we introduce a reference beat which is determined by calculating the mean beat of the ECG recording. Subsequently, the simililarity between the MM of the reference beat and each possible MM combination of a single beat is computed by evaluating a specific cost function. This cost function basically considers the distance to the according R peak, the distance between the MM, and the significance of the detected MM. Logically, for a specific beat, the MM combination with the lowest cost is selected. Comparing Figure 2b and 2c illustrates that this novel strategy significantly improves the P wave segmentation for the second and third beat. In the final paper the proposed approach will be evaluated on the QT database [2], a standard database for testing segmentation algorithms, by comparing our results to those of the algorithm originally proposed in [1].

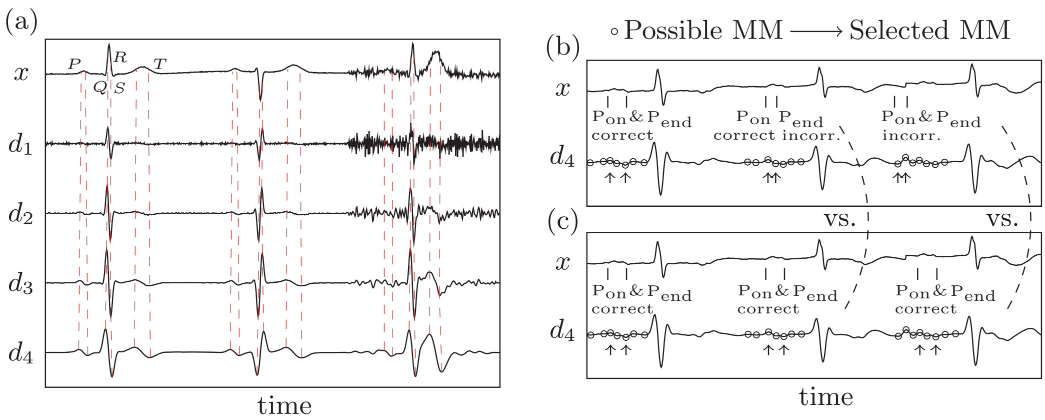


Fig. 2. (a) SDWT for scales $d_1 - d_4$ of different ECG beat morphologies and additional noise, (b) P wave segmentation result for approach proposed in [1] and (c) for approach proposed in this work.

References

1. Martinez, J. P., Almeida, R., Rocha, A.P., Laguna, P.: A Wavelet-Based ECG Delineator Evaluation on Standard Databases. IEEE Transactions on Biomedical Engineering 51, 570–581 (2004).
2. Laguna, P., Mark, R. G., Goldberg, A., Moody, G. B.: A database for evaluation of algorithms for measurement of QT and other waveform intervals in the ECG. In Proceedings of Computers in Cardiology 1997, 673–676, Los Alamitos, CA, (1997).

Heartbeat Classification of ECG Signals Using Rational Function Systems

Gergő Bognár* and Sándor Fridli**

Department of Numerical Analysis, Faculty of Informatics, Eötvös L. University,
Pázmány P. sétány 1/C, Budapest, H-1117 Hungary
bognargergo@caesar.elte.hu,fridli@inf.elte.hu

The importance of automatic electrocardiogram (ECG) analysis is reflected in the intense research activity in this area. Reliable computer-assisted cardiac disorder detection can efficiently contribute the management of clinical situations. There are certain cases, like long-term monitoring, where the timely detection of abnormal heart conditions is a key issue but human-based examination is extremely time-consuming. Automatic heartbeat analysis can assists medical doctors in making a diagnosis of cardiac disorders. Cardiac arrhythmia is a group of conditions in which the heart shows abnormal behaviours or activities. The usual way to categorize the arrhythmia types is the classification of heartbeats into one of the 5 or 16 predefined classes. There have several methods been published using different kind of feature extraction methods and classification algorithms [7, 9, 10]. A common approach is to apply a proper transformation to extract morphological and dynamic features of each heartbeat and use a machine learning classification algorithm [8]. The validation of the methods is performed by using the standard MIT-BIH arrhythmia database (distributed by the Massachusetts Institute of Technology and the Boston's Beth Isreal Hospital) [11] that consists of more than 100 000 heartbeats of 48 signals providing reference annotations for each heartbeat, including the location of the QRS complex and the manually specified class of the heartbeat.

Orthogonal transformations, like the classical trigonometric, wavelet etc. are popular in signal processing with a long history. Yet we propose adaptive rational function systems [1, 2] for heartbeat classification. The so called poles are the parameters of the system that can be adaptively adjusted to the individual signal. Besides its adaptivity another reason why rational function systems are so efficient in ECG processing is that with proper choice of poles, the shapes of the corresponding elements of the rational function system follow the shapes of the segments, i.e. the P and T waves and the QRS complex of heartbeats. Therefore there is a strong connection between the shape of the ECG curve and the poles and coefficients of the rational system. The rational transformation gives a simple analytic representation of the curve with good approximation properties and good compression ratio. In recent years, several applications of rational transforms on ECG signals [1–6] have been published.

* Supported by the New National Excellence Program of the Ministry of Human Capacities of Hungary.

** This research was supported by the Hungarian Scientific Research Funds (OTKA) No K115804.

The rational transform applied to the ECG signal provide the coefficients and the poles which together can serve as morphological features. In addition, four common RR interval parameters as dynamic features are included. A support vector machine classifier is utilized for the classification of heartbeats into one of the 16 classes, independently for two leads of ECG. The fusion of the two decisions gives the final classification result. We validated our method on the MIT-BIH arrhythmia database, where we got an overall accuracy of 99.43% (99.64% with 1%, 99.8% with 1.65% rejection) in the 'class-oriented' evaluation scheme. We note that several issues had to be considered in every phase of the process. For instance in order to get an appropriate rational system to perform the transform one needs to find out the optimal number and multiplicities of the poles along with their locations. On the other hand in the construction of the feature vector a proper balance between local, and global morphological, and dynamic features should be taken care of. Finally, also the design of an effective classification algorithm raised several questions.

References

1. Fridli, S., Lócsi, L., Schipp, F.: Rational Function Systems in ECG Processing. In: Proceedings of EUROCAST 2011, R. Moreno-Dìaz et al. (Eds.) Part I, LNCS, vol. 6927, pp. 88–95. Springer-Verlag, Berlin Heidelberg (2011)
2. Fridli, S., Schipp, F.: Biorthogonal systems to rational functions. Ann. Univ. Sci. Budapest., Sect. Comp., 35, 95–105 (2011)
3. Fridli, S., Kovács, P., Lócsi, L., Schipp, F.: Rational modeling of multi-lead QRS complexes in ECG signals. Ann. Univ. Sci. Budapest., Sect. Comp., 37, 145–155 (2012)
4. Kovács P., Lócsi L.: RAIT: the Rational Approximation and Interpolation Toolbox for Matlab, with Experiments on ECG Signals. International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems, 1, 67–75 (2012)
5. Lócsi, L.: Approximating poles of complex rational functions. Acta Univ. Sapientiae, Mathematica, 1, 169–182 (2009)
6. Gilián, Z., Kovács, P., Samiee, K.: Rhythm-based accuracy improvement of heart beat detection algorithms. In: Computing in Cardiology Conference, pp. 269-272. (2014)
7. Addison, P.S.: Wavelet transforms and the ECG: a review. Physiol. Meas. 26, R155– 99 (2005)
8. Ye, C., Kumar, B.V., Coimbra, M.T.: Heartbeat classification using morphological and dynamic features of ECG signals. IEEE Transactions on Biomedical Engineering, 59, 2930–2941 (2012)
9. Sansone, M., Fusco, R., Pepino, A., Sansone, C.: Electrocardiogram Pattern Recognition and Analysis Based on Artificial Neural Networks and Support Vector Machines: A Review. Journal of Healthcare Engineering, 4, 465–504 (2013)
10. Luz, E.J.S., Schwartz, W.R., Cámara-Cháveza, G., Menotti, D.: ECG-based heartbeat classification for arrhythmia detection: A survey. Computer Methods and Programs in Biomedicine, 127, 144–164 (2016)
11. Goldberger, A.L., et al. : PhysioBank, PhysioToolkit, and Physionet: Components of a New Research Resource for Complex Physiologic Signals. Circulation [Online]. 101, 215–220 (2000). Available: `http://circ.ahajournals.org/cgi/content/full/101/23/e215`

Rational Variable Projection Methods in Signal Processing

Péter Kovács*

Department of Numerical Analysis, Eötvös L. University,
Pázmány Péter sétány 1/C, Budapest, H-1117 Hungary,
kovika@inf.elte.hu

Certain problems in signal processing like compression, feature extraction, etc., can be interpreted as approximation and optimization problems. To this end, an appropriate function space $\mathcal{H}$ is chosen first to the given problem and the signals are considered as the members of this space. In order to simplify the representation, linear models are preferred. Then, the signals $f \in \mathcal{H}$ are usually modeled by finite linear combinations of the elements of a specific function system $\{\Phi_k \,|\, 0 \leq k < n\}$ in such a way that the approximation error is minimized:

$$\operatorname{dist}(f, \mathcal{S}) := \min_{g \in \mathcal{S}} \|f - g\| = \|f - \widehat{f}\| \qquad (\mathcal{S} \subset \mathcal{H}) . \tag{1}$$

For instance, in [1] and [2], the electrocardiographic (ECG) signals were considered as elements of $\mathcal{H} = H^2(\mathbb{D})$ the Hardy space on the open unit disk $\mathbb{D}$, while the function system was the so-called Malmquist–Takenaka (MT) system:

$$\Phi_k(\mathbf{a}; z) = \frac{\sqrt{1 - |a_k|^2}}{1 - \overline{a}_k z} \prod_{j=0}^{k-1} \frac{z - a}{1 - \overline{a} z} \qquad (z \in \overline{\mathbb{D}}\,, 0 \leq k < n) ,$$

where $\mathbf{a} := (a_0, a_1, \ldots, a_{n-1}) \in \mathbb{D}^n$ denotes the inverse pole vector of these rational functions. One can show that for any $f \in H^2(\mathbb{D})$ the radial limit function $f(e^{it}) := \lim_{r \to 1-0} f(re^{it})$ also exists, which belongs to $L^2(\mathbb{T})$ (see e.g., [3]). In this case the norm in Eq (1) can be written as $\|f\| = \|f\|_{L^2(\mathbb{T})}$, where $\mathbb{T}$ denotes the torus and $\|.\|_{L^p(\mathbb{T})}$ is the usual Lebesgue norm. Therefore one can define a scalar product in $H^2(\mathbb{D})$ by

$$\langle f, g \rangle := \frac{1}{2\pi} \int_{-\pi}^{\pi} f(e^{it}) \overline{g}(e^{it}) \, \mathrm{d}t \qquad (f, g \in H^2(\mathbb{D})) .$$

The MT system is an orthonormal function system with respect to this scalar product, hence $\langle \Phi_i(\mathbf{a}; \cdot), \Phi_j(\mathbf{a}; \cdot) \rangle = \delta_{ij}$ $(0 \leq i, j < n)$ for any $\mathbf{a} \in \mathbb{D}^n$. Thanks to this property and the fact that $(H^2(\mathbb{D}), \langle \cdot, \cdot \rangle)$ is a Hilbert space, the orthogonal projection to $\mathcal{S}(\mathbf{a}) := \operatorname{span}\{\Phi_k(\mathbf{a}; \cdot) \,|\, 0 \leq k < n\}$ gives the solution to the minimization problem in Eq. (1). The orthogonal projection can be easily calculated as

$$\mathcal{S}(\mathbf{a}) \ni \widehat{f}(\mathbf{a}; z) := \sum_{k=0}^{n-1} \langle f(\cdot), \Phi_k(\mathbf{a}; \cdot) \rangle \, \Phi_k(\mathbf{a}; z) ,$$

* This research was supported by the Hungarian Scientific Research Funds (OTKA) No K115804.

where $\mathbf{a} \in \mathbb{D}^n$ is a given inverse pole vector. Note that the subspace $S(\mathbf{a})$ depends on the parameter vector $\mathbf{a}$ (cf. Eq. (1)), thus the rational approximation $\widehat{f}(\mathbf{a}; z)$ is an adaptive signal model.

Proper selection of the features is of key importance in data reduction problems such as signal compression, smoothing and classification. Hence the parameter vector $\mathbf{a}$ must be adequately chosen. To this end the following optimization problem is considered:

$$\min_{\mathbf{a}\in\mathbb{D}^n} r_2(\mathbf{a}) := \min_{\mathbf{a}\in\mathbb{D}^n} \|f(\cdot) - \widehat{f}(\mathbf{a};\cdot)\|_{L^2(\mathbb{T})} ,$$

where $r_2(\mathbf{a})$ is the so-called variable projection functional [4].

In this work, we will construct a compact signal model for $f \in H^2(\mathbb{D})$ by finding the optimal inverse pole vector $\mathbf{a} \in \mathbb{D}^n$, which minimizes $r_2(\mathbf{a})$. In order to avoid getting stuck in local minima, we will use global optimization techniques such as the hyperbolic variation of the particle swarm optimization HPSO algorithm [5]. Local optimizations like Gauss–Newton type methods can also be used to improve the results of HPSO. We will recall these algorithms and demonstrate their performance on real ECG signals of the PhysioNet MIT-BIH database [6]. Although our case study includes only ECG signals, the proposed algorithm can be applied to other signals as well (see e.g., [7] and [8]).

References

1. Fridli, S., Lócsi, L., Schipp, F.: Rational Function System in ECG Processing. In: Moreno-Díaz et al. (eds.) Computer Aided Systems Theory–EUROCAST 2011. LNCS, vol. 6927, pp. 88–95. Springer, Heidelberg (2011).
2. Fridli, S., Kovács, P., Lócsi, L., Schipp, F.: Rational Modeling of Multi-Lead QRS Complexes in ECG Signals, Annales Univ. Sci. Budapest Sect. Comp. 37, pp. 145–155 (2012).
3. A. Zygmund.: Trigonometric Series I. - II. Cambridge University Press, UK (1959).
4. Golub, G.H., Pereyra, V.: The Differentiation of Pseudo-Inverses and Nonlinear Least Squares Problems whose Variables Separate. SIAM Journal on Numerical Analysis. 10, pp. 413–432 (1973).
5. Kovács, P., Kiranyaz, S., Gabbouj, M.: Hyperbolic Particle Swarm Optimization with Application in Rational Identification. In: 21st European Signal Processing Conference (EUSIPCO), pp. 1–5. IEEE Press, New York (2013).
6. Goldberger, A.L., Amaral, L.A.N., Glass, L., Hausdorff, J.M., Ivanov, P.Ch., Mark, R.G., Mietus, J.E., Moody, G.B., Peng, C.K., Stanley, H.E.: PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. Circulation. 101, pp. 215–220 (2000).
7. Samiee, K., Kovács, P., Gabbouj, M.: Epileptic Seizure Classification of EEG Time-Series Using Rational Discrete Short Time Fourier Transform. IEEE Transactions on Biomedical Engineering (TBME). 62, pp. 541–552 (2014).
8. Samiee, K., Kovács, P., Kiranyaz, S., Gabbouj, M., Saramäki, T.: Sleep Stage Classification Using Sparse Rational Decomposition of Single Channel EEG Records. In: 23rd European Signal Processing Conference (EUSIPCO), pp. 1905–1909. IEEE Press, New York (2015).

From Heart Rate Variability to Autonomic Nervous System - Poincaré plot vs. Spectral Analysis

Christoph Mahringer[1,2], Walter Struhal[3], Michael Lunglmayr[1], Carl Böck[1] and Mario Huemer[1]

[1]Institute of Signal Processing, Johannes Kepler University, Linz.
{carl.boeck,michael.lunglmayr,mario.huemer}@jku.at
[2]Department for Biomedical Engineering,
Kepler University Hospital, Linz.
[3]Department of Neurology 2,
Kepler University Hospital, Linz.
{christoph.mahringer,walter.struhal}@kepleruniklinikum.at

The heart rate variability (HRV) is a measure that plots the instant interval between two consecutive heartbeats (R-peaks) over time. The interval is measured from one ventricle contraction of heartbeat $n-1$ to the next contraction of heartbeat n. Since heart frequency changes the HRV $R[n]$ represents a non-equidistant sequence. This sequence contains fundamental information about the condition of the individual heart and the cardiovascular regulatory mechanisms of the autonomic nervous system (ANS) [1].

A common method of visualization of HRV data is the Poincaré plot (Fig. 1), a scatterplot showing $R[n+1]$ over $R[n]$, which is used to categorize data into functional classes, indicating the integrity of the heart and possible heart failures [2]. For assessing information about the ANS two parameters of the Poincaré plot are frequently used. The parameter SD1 contains information about vagal efferent activity (parasympathetic tone) and SD2, is a measure for the combination of sympathetic and parasympathetic tone [3]. Fig. 1 shows a Poincaré-plot of a patient without autonomic dysfunction in supine position. Another way to evaluate the two branches of the ANS has been shown in [4]. There, spectral analysis of the HRV by a continuous wavelet transformation (CWT) with a non-analytical Morlet wavelet has been applied to confirm the presence of an autonomic dysfunction in demented patients. The change from time-domain analysis to time-frequency analysis appears to be a paradigm change in the medical society, which should be evaluated for validity also from a technical point of view. Therefore we compared the scatterplot dependent ANS evaluation results with the performance of the CWT using the same dataset we presented in [4]. Furthermore, we

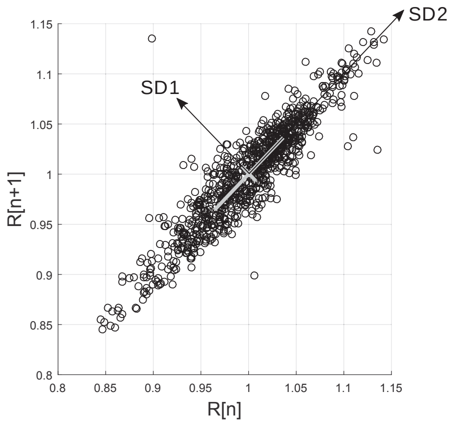


Fig. 1. Scatterplot with $SD1$ and $SD2$ (in grey)

modified the scatterplot metric to improve its application for ANS evaluation in demented patients.

	Patients without autonomic dysfunction		Patients with autonomic dysfunction	
x	$\tilde{x}_{HUT} - \tilde{x}_{SUPINE}$	p-value [%]	$\tilde{x}_{HUT} - \tilde{x}_{SUPINE}$	p-value [%]
$SD1[\mu s]$	-3.8	11.9	-1.3	19
$SD2[\mu s]$	2.7	84.2	-5.9	39.5
P_{LF} [%][4]	6.5†	3.5	2.3	39.5
P_{HF} [%][4]	-6.5†	3.5	-2.3	39.5
modified Scatterplot metric				
$SD1[\%]$	-4.3†	4.23	-0.3	83.6
$SD2[\%]$	4.3†	4.23	0.3	83.6

Table 1. Difference in median values of characteristic parameters x extracted from the HRV according to postural challenge ($\tilde{x}_{HUT} - \tilde{x}_{SUPINE}$) within each patient group with corresponding p-values. ($\dagger \cdots$ significant at level 0.05)

In [4] we showed that for demented patients without autonomic dysfunction a significant modulation of autonomic activity occurs in the low-frequency (LF) band during postural challenge. This allows to distinguish this group from the patient group with autonomic dysfunction where no significant autonomic modulation was detectable in the LF band. Table 1 shows exemplary results of the Wilcoxon rank sum test for equality of the medians of CWT and scatterplot parameters comparing the supine and the Head Up Tilt (HUT) position of each patient group. Only the normalized power (P_{LF}, P_{HF}) (already used in [4]) and the modified scatterplot parameters have been able to reflect autonomic modulation in patients without autonomic dysfunction thus distinguishing the two patient groups and therefore being possibly helpful in diagnosing hampered autonomic modulation. However, calculating the CWT is much more complex than calculating the scatter plot based metrics. Especially when thinking about implementing such detection algorithms in battery powered devices this presents a huge disadvantage. In this work we present strategies to improve the detection quality of the scatter plot based metrics $SD1$ and $SD2$ that finally show a similar detection quality as the CWT based approach.

References

1. Malik, M., Bigger, J., Camm, A.: Heart rate variability standards of measurement, physiological interpretation, and clinical use. Eur. Heart J. 17, 354–381 (1996).
2. Brennan, M., Palaniswami, M., Kamen, P.: Do existing measures of Poincaré plot geometry reflect nonlinear features of heart rate variability? IEEE Trans. Biomed. Eng. 48, 1342–1347 (2001).
3. Hoshi, R. A., Pastre, C. M., Vanderlei, L. C. M., Godoy, M. F.: Poincaré plot indexes of heart rate variability: Relationships with other nonlinear variables. Auton. Neurosci. Basic Clin. 177, 271–274 (2013).
4. Struhal, W., Mahringer, C., Lahrmann, H., Moertl, C., Buhl, P., Huemer, M., Ransmayr, G.: Heart Rate Spectra Confirm the Presence of Autonomic Dysfunction in Dementia Patients. J. Alzheimers. Dis. 54, 657–667 (2016).

Arithmetic Operations with Droplet-Based Microfluidic Systems

Werner Haselmayr

Institute for Communications Engineering and RF-Systems
Johannes Kepler University Linz, Austria
werner.haselmayr@jku.at

1 Introduction

Droplet-based microfluidic systems refer to systems, where tiny volumes of fluids, so-called droplets, flow in channels of micrometer scale [1]. Typically, the droplets are generated using a T-junction, where a fluid (dispersed phase) in form of droplets is dispersed into another immiscible fluid (continuous phase), acting as carrier fluid. Initially, droplet-based microfluidic systems were introduced approximately one decade ago, as a promising platform for advanced diagnostics and therapeutics [2]. However, recently droplet-based microfluidics have been used for information transmission and simple computing. In [3], for the first time, a simple droplet-based communication system was proposed. The idea of information transmission was extended in [4], by introducing different methodologies for information encoding using droplets, e.g., the presence/absence of droplets or the distance between two consecutive droplets. A first step towards computing in microfluidic systems was made in [5, 6], by implementing Boolean functions (e.g., AND gate) in the microfluidic domain. However, to the best of our knowledge, no work has been devoted to enabling arithmetic operations in droplet-based microfluidic systems.

2 Droplet-Based Computation

To enable arithmetic operations in droplet-based microfluidic systems, we adapt the concept of stochastic computation (SC) [7] for the microfluidic domain.
In conventional stochastic computation a fractional number between 0 and 1 is represented by a serial stochastic bit stream. The occurrence of 1's in a bit stream relative to the stream length describes the desired number. For example, a bit stream of length 10 including 5 1's, represents the number 5/10. It is important to note that the position of 1's in the stream is not prescribed and, thus, different streams exists for the same number. In SC arithmetic operations are performed using simple logic circuits, e.g., a multiplication can be implemented using an AND gate. Thus, the benefits of SC are twofold. First, since the information lies in the stream and not in the individual bits, SC has an inherent fault tolerance[1] and requires no synchronization among the streams. Second, SC

[1] A bit flip in a serial stochastic stream does not significantly change the represented number. In conventional binary radix encoding a bit flip may cause huge errors, depending on the location of the flipped bit.

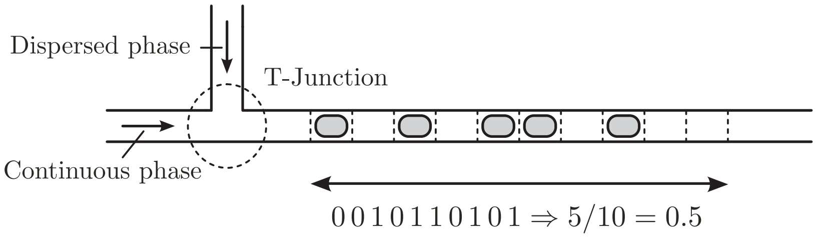


Fig. 1. Droplet stream representing the number $5/10 = 0.5$.

allows to implement arithmetic operations using low-complexity logic circuits. However, a drawback of SC is the long computation time, since a high-precise number representation requires long streams. Thus, SC is especially suitable for low-precision applications, e.g., decoding of low-density parity-check codes [8]. Obviously, a droplet stream can realize a serial stochastic bit stream, as required for SC. Therefore, the droplet transmission is divided into time slots and a droplet is generated for a 1 and no droplet for 0. A droplet stream representing the number 0.5 is shown in Fig. 1. Thus, applying droplets streams to the microfluidic logic gates proposed in [5,6] enables droplet-based microfluidic systems to perform arithmetic operations.

In this paper we introduce the adaption of the stochastic computation concept for the microfluidic domain. Furthermore, we present the implementation of arithmetic operations based on microfluidic logic circuits and finally, we validate our approach through computer simulations and discuss the constraints of our approach in real-life applications.

References

1. D. Mark et al., "Microfluidic lab-on-a-chip platforms: requirements, characteristics and applications," *Chemical Society Reviews*, vol. 39, no. 3, pp. 1153–1182, 2010.
2. S.-Y. Teh et al., "Droplet microfluidics," *Lab on a Chip*, vol. 8, pp. 198–220, 2008.
3. M. J. Fuerstman, P. Garstecki, and G. M. Whiteside, "Coding/decoding and reversibility of droplet trains in microfluidic networks," *Science*, vol. 315, no. 5813, pp. 828 – 832, 2007.
4. E. De Leo et al., "Networked labs-on-a-chip (NLoC): Introducing networking technologies in microfluidic systems," *Nano Communication Networks*, vol. 3, no. 4, pp. 217 – 228, 2012.
5. L. F. Cheow, L. Yobas, and D.-L. Kwong, "Digital microfluidics: Droplet based logic gates," *Applied Physics Letters*, vol. 90, no. 5, 2007.
6. M. Prakash and N. Gershenfeld, "Microfluidic bubble logic," *Science*, vol. 315, no. 5813, pp. 832–835, 2007.
7. A. Alaghi and J. P. Hayes, "Survey of stochastic computing," *ACM Trans. Embed. Comput. Syst.*, vol. 12, no. 2s, pp. 92:1–92:19, May 2013.
8. S. S. Tehrani, W. J. Gross, and S. Mannor, "Stochastic decoding of LDPC codes," *IEEE Commun. Lett.*, vol. 10, no. 10, Oct. 2006.

Determination of Parasitic Capacitances in Inductive Components - A Comparision between Analytic Calculation Methods and FEM-Simulation

Simon Merschak[1], Mario Jungwirth[1], Daniel Hofinger[2], Alexander Eder[2], Günter Ritzberger[2]

[1] University of Applied Sciences Upper Austria, Campus Wels
Stelzhamerstrasse 23, 4600 Wels, Austria
{simon.merschak,mario.jungwirth}@fh-wels.at
http://www.fh-ooe.at
[2] Fronius International GmbH, Research & Development
Günter Fronius Strasse 1, 4600 Wels-Thalheim, Austria
{hofinger.daniel,eder.alexander,ritzberger.guenter}@fronius.com
http://www.fronius.at

1 Introduction

Flyback converters are commonly used in switching mode power supplies. An essential component of a flyback converter is the high-frequency transformer. In order to ensure a faultless operation of the converter even at high operating frequencies, the parasitic capacitive effects in the transformer have to be considered during the engineering process. The negative effects of the parasitic capacitances on the currents in the converter windings increase with rising operation frequency [1]. The aim of this paper is to draw a comparison between analytic calculation methods and FEM simulations by means of a sample transformer model. Additionally the effects of the parasitic capacitances on the converter currents are presented.

2 Methods of Calculation

There are two different approaches for the calculation of parasitic capacitances in transformers. The first one is based on easy to use equations which depend on a strong simplification of the complex task. The second one applies the finite element method to calculate a matrix of parasitic capacitances. The computational cost of the second approach is significantly higher [2]. Hence it is evaluated if the analytic approach is applicable for an automated calculation of the parasitic capacitances or if the finite element method has to be used. It is also verified that the dynamic component of the electric field can be neglected for the calculation of the parasitic capacitances for frequencies up to a few hundred kilohertz.

3 Comparison of Results

Calculation and simulation of the turn-to-turn and layer-to-layer capacitances are conducted by use of simple coil models. The capacitances are calculated using analytical equations in Wolfram Mathematica and are compared to simulations performed in Comsol Multiphysics ®.

4 Effects of the parasitic Capacitances

To demonstrate the impact of parasitic capacitances on the currents of a flyback converter, a SPICE simulation is implemented. The simulation is conducted with and without the prior determined parasitic capacitances. The parasitic capacitances are modelled as lumped capacitors in the simulation. The simulation results are compared with measurement results. It becomes apparent that the parasitic capacitances have an significant influence on the converters primary and secondary current.

5 Conclusion and future prospects

The parasitic turn-to-turn capacitance is calculated with two different equations [1]. The first one is valid for conductors which are in contact at the insulation surface. The calculated capacitance is 2.63 pF and the equivalent simulation result is 2.66 pF. If the distance between the conductors is increased, another equation has to be used and the conformity is not so good anymore. The difference is about 30% and can be explained by the limited range of validity for the input parameters of the analytic equations. The layer-to-layer capacitance is calculated by use of the cylindrical capacitor model [3]. The result is 14.93 pF and is therefore underestimating the simulation result by 12%. Analytic equations are suitable to estimate the parasitic capacitances of a specific transformer but they are not suitable for an automated calculation of them. The reason for this is that there are numerous analytic equations for different use cases and each equation is only valid for a specific range of input parameters. A FEM-based approch is prefered for the automated calculation of parasitic capacitances. Future steps will be to conduct a 3D simulation in the software ANSYS Maxwell to determine the influence of edge effects which are neglegted in the 2D simulation.

References

1. Massarini, A. and Kazimierczuk, M.: Self-capacitance of inductors. IEEE Transactions on Power Electronics, 12(4), pp.671-676, (1997)
2. Dalessandro, L., da Silveira Cavalcante, F. and Kolar, J.: Self-Capacitance of High-Voltage Transformers. IEEE Transactions on Power Electronics, 22(5), pp.2081-2092, (2007)
3. Biela, J. and Kolar, J.: Using Transformer Parasitics for Resonant Converters - A Review of the Calculation of the Stray Capacitance of Transformers. IEEE Transactions on Industry Applications, 44(1), pp.223-233, (2008)

Review of UHF based Signal Processing Approaches for Partial Discharge Detection

Thomas Schlechter, Benjamin Schubert, and Mario Ludwig

State Grid Global Energy Interconnection Research Institute Europe GmbH
Markgrafenstr. 34, 3rd Floor, 10117 Berlin, Germany
{t.schlechter,benjamin.schubert,m-ludwig}@geiri.sgcc.com.cn

Partial Discharge (PD) is a common reason for failures in power stations [1]. Various kinds of PD sources have been discovered and characterized in the past, which are more or less malicious for the overall system. Additionally, each type of PD has its specific fingerprint within possible signal representations of the latter's occurrence. While many different physical layers of representation of PD pulses may be thought of [2], in very recent years one method gained high interest among researchers and also power plant operators, which explores the ultra high frequency (UHF) components contained in the electromagnetic signal generated by PD events [1, 2].

A crucial point towards implementing such an installation is the possibility, to extract the UHF signal and its parameters of interest from a received signal containing both multiple signals caused by PD sources and noise. As there is comparably little knowledge about real systems, currently plenty of different signal processing approaches can be observed in the community. For instance, a method for UHF PD source detection has been proposed, which is based on energy estimations along four different frequency ranges in the analog domain [3]. Based on the spectrum estimation for these ranges a classification and characterization of the PD pulse can be done. Different approaches use averaging of consecutive sample data sets for extracting the wanted signal from the noisy background [4] and/or discrete wavelet implementations, which are very well suited for extracting characteristic features from the underlying signal [4, 5]. Further methods are based on Empirical Mode Decomposition (EMD) [6] or foster investigations towards using Neural Networks (NN) [7] or Support Vector Machines (SVM) [5, 8]. Those are suited for discovering properties of non-stationary signals in the time domain (EMD), optimized classification of data sets generating an optimal decision corridor between adjacent classes (SVM), and introducing advanced machine learning algorithms into the field of PD detection (NN). Alternative approaches can be found using the Cumulative Energy Function [9], allowing a data compression in frequency and time domain in parallel, Mathematical Morphology Gradient Implementations [6, 9], exploring virtual geometric structures contained in the PD data, and Generalized S-Transform and Module Time-Frequency Matrix [10], which also allows analyzing the underlying data in both the frequency and time domain. Finally, one more method has to be mentioned, which is based on Spatial Clustering and allows to reduce the input sampling rate of the UHF receiver, which is an important property for low power sensor nodes [11].

Currently, plenty of concurrent methods on PD evaluation in the UHF range are under investigation. Real world field tests will show, which method or combination of methods will be the most suitable. As a follow-up of the research presented in this paper, this aspect will be covered in a deeper sense.

References

1. M. Siegel, M. Beltle, and S. Tenbohlen, "Characterization of UHF PD sensors for power transformers using an oil-filled GTEM cell," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 23, no. 3, pp. 1580–1588, June 2016.
2. I. A. Soomro and M. N. Ramdon, "Study on different techniques of partial discharge (PD) detection in power transformers winding: Simulation between paper and EPOXY resin using UHF method," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 2, no. 1, Apr. 2014.
3. Y. Zhang, D. Upton, A. Jaber, H. Ahmed, B. Saeed, P. Mather, P. Lazaridis, A. Mopty, C. Tachtatzis, R. Atkinson, M. Judd, M. de Fatima, Q. Vieira, and I. Glover, "Radiometric Wireless Sensor Network Monitoring of Partial Discharge Sources in Electrical Substations," *Int. Journal of Distr. Sensor Networks*, vol. 11, no. 9, pp. 1–9, Sep. 2015.
4. S. M. Markalous, S. Tenbohlen, and K. Feser, "Detection and Location of Partial Discharges in Power Transformers using Acoustic and Electromagnetic Signals," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 15, no. 6, pp. 1576–1583, Dec. 2008.
5. H. de Oliveira Mota, L. C. D. da Rocha, T. C. de Moura Salles, and F. H. Vasconcelos, "Partial discharge signal denoising with spatially adaptive wavelet thresholding and support vector machines," *Electr. Power Systems Research*, vol. 81, no. 2, pp. 644–659, Feb. 2011.
6. J. Chan, H. Ma, T. Saha, and C. Ekanayake, "Self-adaptive partial discharge signal de-noising based on ensemble empirical mode decomposition and automatic morphological thresholding," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 21, no. 1, pp. 294–303, Feb. 2014.
7. J.-C. Hsieh, C.-C. Tai, M.-S. Su, and Y.-H. Lin, "Identification of Partial Discharge Location Using Probabilistic Neural Networks and the Fuzzy C-means Clustering Approach," *Electr. Power Comp. and Systems*, vol. 42, no. 1, pp. 60–69, Dec. 2013.
8. M. R. Velayutham, S. Perumal, V. Basharan, and W. I. M. Silluvairaj, "Support Vector Machine-based Denoising Technique for Removal of White Noise in Partial Discharge Signal," *Electr. Power Comp. and Systems*, vol. 42, no. 14, pp. 1611–1622, Sep. 2014.
9. M.-X. Zhu, J.-N. Zhang, Y. Li, Y.-H. Wei, J.-Y. Xue, J.-B. Deng, H.-B. Mu, G.-J. Zhang, and X.-J. Shao, "Partial discharge signals separation using cumulative energy function and mathematical morphology gradient," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 23, no. 1, pp. 482–493, Feb. 2016.
10. Y. Liu, W. Zhou, P. Li, S. Yang, and Y. Tian, "An Ultrahigh Frequency Partial Discharge Signal De-Noising Method Based on a Generalized S-Transform and Module Time-Frequency Matrix," *Sensors*, vol. 16, no. 6, p. 941, Jun. 2016.
11. J. Ardila-Rey, J. Martinez-Tarifa, G. Robles, and M. Rojas-Moreno, "Partial discharge and noise separation by means of spectral-power clustering techniques," *IEEE Trans. Dielectr. and Electr. Insul.*, vol. 20, no. 4, pp. 1436–1443, Aug. 2013.

Gibbs Dyadic Differentiation on Groups - Evolution of the Concept

Radomir S. Stanković, [1]Jaakko Astola, [2]Claudio Moraga

Dept. of Computer Science, Faculty of Electronic Engineering, Niš, Serbia
[1]Dept. of Signal Processing, Tampere University of Technology, Tampere, Finland
[2]Faculty of Computer Science, Technical University of Dortmund, Dortmund, Germany

The Walsh dyadic analysis emerged in late sixties and early seventies as a mathematical discipline aimed at providing a form of spectral Fourier-like analysis tailored for signals modeled by two-level piecewise constant functions and, therefore, making them compatible with digital computing devices based on elements with two sable states. At the same time, the dyadic analysis provided an answer to demands for a spectral analysis with simplified computations because the limited computing power of computing devices at that time.

The relentless complexity of contemporary and future digital systems, regains a new interest to Walsh dyadic analysis. Being primarily intended as a mathematical support in solving various signal processing and system design tasks, the dyadic analysis immediately required the concept of a derivative that will enable differentiation of piecewise constant functions.

The answer was provided by James Edmund Gibbs who introduced the concept that is now called the Gibbs dyadic derivative as follows [4].

Consider the group G_n whose elements are the n-tuples $x = (x_0, x_1, \ldots, x_{n-1})$ with $x_i \in \{0, 1\}$, and the group operation is coordinatewise addition modulo 2 denoted by $\oplus$. For each function f in the space L_n of all bounded complex-valued function on G_n, the Gibbs dyadic derivative is a function $f^{[1]} \in L$ defined by

$$f^{[1]}(x) = -\frac{1}{2}\sum_{r=0}^{n-1}(f(x \oplus 2^r) - f(x))2^r.$$

In a report from April 1970, in Section 4.1 entitled Dyadic differentiation, F. Pichler extended this definition to real valued functions of a continuous nonnegative real variable by attaching, if possible, to each function another function [7]

$$f^{[1]}(x) = \sum_{k=-\infty}^{\infty}(f(t) - f(t \oplus 2^{-k}))2^{k-2},$$

called the first dyadic derivative.

Two papers [1] and [3], introducing the concept of the Butzer-Wagner derivative, which can be viewed as the extension of the concept of the dyadic differentiation to infinite dyadic group, alternatively the interval $[0, 1)$, were completed in preprint form in the autumn of 1971. See, also [2]. The Butzer-Wagner derivative is defined for $x \in [0, 1)$ as

$$f^{[1]}(x) = \frac{1}{2}\sum_{j=1}^{\infty}2^{-j}(f(x) - f(x \oplus 2^{-j})),$$

where $x = \sum_{j=1}^{\infty} x_j 2^{-j}$, $y = \sum_{j=1}^{\infty} y_j 2^{-j}$, for $x_j, y_j \in [0,1)$, and the addition is defined as $x \oplus y = \sum_{j=1}^{\infty} |x_j - y_j| 2^{-j}$.

Since starting from the initial definitions, these operators were viewed as differential operators for functions on groups, the same line of thinking was continued by J.E. Gibbs and his associates [5], [6], and have also been accepted by several other authors [11]. The scope of the definition was extended and generalized to various Abelian and finite and compact non-Abelian groups [8], [9], [10] including also differentiation of different classes of signals and two-dimensional signals [12].

In this paper, we discuss evolution of the concept of the Gibbs dyadic differentiation and provide a classification of these differential operators on groups. We also point the fields of applications of these differential operators.

References

1. Butzer, P.L., Wagner, H.J., ”Approximation by Walsh polynomials and the concept of a derivative”, *Proc. Sympos. Applic. Walsh Functions*, Washington, D.C., 1972, 388-392.
2. Butzer, P.L., Wagner, H.J., ”On a Gibbs-type derivative in Walsh-Fourier analysis with applications”, *Proc. Nat. Electron. Conf.*, Vol. 27, 1972, 393-398.
3. Butzer, P.L., Wagner, H.J., ”Walsh-Fourier series and the concept of a derivative”, *Applicable Anal.*, 3, 1973, 29-46
4. Gibbs, J.E., ”Walsh spectrometry, a form of spectral analysis well suited to binary digital computation”, Nat. Phys. Lab., Teddington, Middx, UK, 1967, 24pp.
5. Gibbs, J.E., Ireland, B., ”Some generalizations of the logical derivative”, DES Report No. 8, Nat. Phys. Lab., August 1971, 22+ii pages.
6. Gibbs, J.E., J. Simpson, ”Differentiation on finite Abelian groups”, Nat. Phys. Lab., Teddington, Middx, UK, 1974, 34pp.
7. Pichler, F.R., *Some Aspects of A Theory of Correlation with Respect to Walsh Harmonic Analysis*, Technical Report Rept R-70-11, Univ. Maryland Tech. Res., 1970.
8. Stanković, R.S., ”A note on differential operators on finite non-Abelian groups”, *Applicable Anal.*, Vol. 21, No. 1-2, 1986, 31-41.
9. Stanković, R.S., ”Gibbs derivatives on finite non-Abelian groups”, in Butzer, P.L., Stankovic, R.S. (edit.), *Theory and Applications of Gibbs Derivatives: Proceedings of the First International Workshop on Gibbs Derivatives*, September 26-28, 1989, Kupari-Dubrovnik, Yugoslavia, Matematički Institut, Beograd, 1990, 269-297
10. Stanković, R.S., Astola, J.T., ”Remarks on the development and recent results in the theory of Gibbs derivatives”, *Facta Universitatis, Ser. Elec. Energ.*, Vol. 21, No. 3, 2008, 349-364.
11. Stanković, R.S., Astola, J.T., *Gibbs Derivatives - the First Forty Years*, TICSP Series #39, Tampere International Center for Signal Processing, Tampere, Finland, 2008, ISBN 978-952-15-1973-4, ISSN 1456-2774.
12. Stanković, R.S., Butzer, P.L., Schipp, F., Wade, W.R., Su, W., Endow, Y., Fridli, S., Golubov, B.I., Pichler, F., Onnewerr, K.C.W., *Dyadic Walsh Analysis from 1924 Onwards, Walsh-Gibbs-Butzer Dyadic Differentiation in Science, Volume 2, Extensions and Generalizations, A Monograph Based on Articles of the Founding Authors, Reproduced in Full*, Atlantis Press, Atlantis Studies in Mathematics for Engineering and Science, 2015, ISBN 978-94-6239-162-8, ISBN 978-94-6239-163-5 (eBook).

A Hierarchy of Models for Lattices of Boolean Functions

Bernd Steinbach[1] and Christian Posthoff[2]

[1] Freiberg University of Mining and Technology, Institute of Computer Science, D-09596 Freiberg, Germany
[2] The University of The West Indies, St. Augustine Campus, Trinidad & Tobago

Abstract. The utilization of lattices of Boolean functions for the synthesis of circuits combines the benefits of more freedom for optimization with limited calculations on mark functions. We extend the known hierarchy of lattices by a third level.

1 Introduction

Boolean functions specify the output values for all input combinations. Very often not all combinations are needed. Functions for which not all output values are specified are called *incompletely specified functions* (ISF). ISFs play a central role in the optimization of logic circuits as they represent the degrees of freedom for the assignment of a circuit structure [1].

From another point of view an ISF represents a set of Boolean functions from which an arbitrary one can be selected and realized in a circuit. An ISF with $|f_\varphi|$ don't cares specifies a set of $2^{|f_\varphi|}$ completely specified Boolean functions. This set of functions satisfies the rules of a Boolean lattice.

2 Three Mark Functions of a First-Level Lattice

A benefit of a lattice is that an exponential number of Boolean functions can be described by two of the three mark functions $f_q(\mathbf{x})$, $f_r(\mathbf{x})$, and $f_\varphi(\mathbf{x})$. The set of all 2^n input patterns $\mathbf{x} = (x_1, x_2, \ldots, x_n)$ of an incompletely specified function can be divided into three disjoint sets:

- $\mathbf{x} \in$ don't-care-set $\Leftrightarrow f_\varphi(x_1, \ldots, x_n) = 1$
  $\Leftrightarrow$ it is allowed to choose the function value of f without any restrictions,
- $\mathbf{x} \in$ ON-set $\Leftrightarrow f_q(x_1, \ldots, x_n) = 1$
  $\Leftrightarrow (f_\varphi(x_1, \ldots, x_n) = 0) \wedge (f(x_1, \ldots, x_n) = 1)$,
- $\mathbf{x} \in$ OFF-set $\Leftrightarrow f_r(x_1, \ldots, x_n) = 1$
  $\Leftrightarrow (f_\varphi(x_1, \ldots, x_n) = 0) \wedge (f(x_1, \ldots, x_n) = 0)$.

A function $f(\mathbf{x})$ belongs to a first-level lattice $L^1 \langle f_q(\mathbf{x}), f_r(\mathbf{x}) \rangle$ if it satisfies the condition:

$$\overline{f(\mathbf{x})} \wedge f_q(\mathbf{x}) \vee f(\mathbf{x}) \wedge f_r(\mathbf{x}) = 0 \ . \tag{1}$$

3 Second-Level Lattices of Boolean Functions

Derivative operations of the Boolean Differential calculus are very useful for the synthesis of circuits [2]. Such operations can be executed for lattices of Boolean function based on their mark functions. The results of vectorial derivative operations are lattices that can not expressed by (1). A more general definition for such second-level lattices $L^2 \left\langle f_q(\mathbf{x}), f_r(\mathbf{x}), f^{id_2}(\mathbf{x}) \right\rangle$ was published in [3, 4, 5]:

$$\overline{f(\mathbf{x})} \wedge f_q(\mathbf{x}) \vee f(\mathbf{x}) \wedge f_r(\mathbf{x}) \vee \bigvee_{i=1}^{k} \frac{\partial f(\mathbf{x})}{\partial \mathbf{x}_{0i}} = 0 \ , \tag{2}$$

where $f^{id_2}(\mathbf{x})$ (the independency function of the level 2) is the disjunction of certain vectorial derivatives as shown as last term in (2).

4 Third Level in the Hierarchy of Lattices

A lattice L^2 as described in (2) can be the result of a vectorial derivative of a lattice L^1. Lattices L^2 have the benefit that they describe only functions that are independent of certain directions of change. However, there are lattices which do not satisfy this strong requirement for the whole Boolean space, but for the region of the don't-care-set. Lattices $L^3 \left\langle f_q(\mathbf{x}), f_r(\mathbf{x}), f^{id_2}(\mathbf{x}), f^{id_3}(\mathbf{x}) \right\rangle$ of this new third level in the hierarchy of lattices are defined by:

$$\overline{f(\mathbf{x})} \wedge f_q(\mathbf{x}) \vee f(\mathbf{x}) \wedge f_r(\mathbf{x}) \vee \bigvee_{i=1}^{k} \frac{\partial f(\mathbf{x})}{\partial \mathbf{x}_{0i}} \vee f_\varphi(\mathbf{x}) \wedge \left(\bigvee_{j=1}^{l} \frac{\partial f(\mathbf{x})}{\partial \mathbf{x}_{0j}} \right) = 0 \ , \tag{3}$$

where $f^{id_3}(\mathbf{x})$ (the independency function of the level 3) is the disjunction of certain vectorial derivatives restricted to $f_\varphi(\mathbf{x}) = 1$ as shown as last term in (3).

References

1. Brayton, R.K., Hachtel, G.D., McMullen, C.T., and Sangiovanni-Vincentelli, A.: Logic Minimization Algorithms for VLSI Synthesis. Kluwer Academic Publishers, 1984.
2. Posthoff, Ch. and Steinbach, B.: Logic Functions and Equations - Binary Models for Computer Science. Springer, Dordrecht, The Netherlands, 2004.
3. Steinbach, B.: Generalized Lattices of Boolean Functions Utilized for Derivative Operations. in: Materiały konferencyjne KNWS13, Łagów, Poland, 2013, DOI: 10.13140/2.1.1874.3680, pp. 1–17.
4. Steinbach, B. and Posthoff, Ch.: Derivative Operations for Lattices of Boolean Functions. in: Proceedings Reed-Muller Workshop 2013, Toyama, Japan, 2013, DOI: 10.13140/2.1.2398.6568, pp. 110–119.
5. Steinbach, B. and Posthoff, Ch.: Boolean Differential Equations - a Common Model for Classes, Lattices, and Arbitrary Sets of Boolean Functions. in: FACTA UNIVERSITATIS (NI), Series: Electronics And Energetics. Volume 28, Issue No. 1, ISSN 0353-3670, DOI: 10.2298/FUEE1501051S, March, 2015, pp. 51–76.

The inverse of the continuous wavelet transform

Ferenc Weisz*

Department of Numerical Analysis, Eötvös L. University,
Pázmány Péter sétány 1/C, Budapest, H-1117 Hungary,
weisz@inf.elte.hu

Wavelet analysis has established itself in the last 20-30 years as a fertile branch of analysis, and has a lot of links to real world applications, e.g. to image and signal analysis and to storage of fingerprints. There are many interesting books in this area, e.g. Daubechies [2], Hernandez and Weiss [6], Walnut [10], moreover several papers have appeared ([1, 7–9, 13–15]). The continuous wavelet transform of f with respect to a wavelet g is defined by

$$W_g f(x,s) = \langle f, T_x D_s g\rangle \qquad (x \in \mathbb{R}, s \in \mathbb{R}, s \neq 0),$$

where D_s is the dilation operator and T_x the translation operator. Under some conditions on g and γ the inversion formula holds for all $f \in L_2(\mathbb{R})$:

$$\int_{\mathbb{R}} \int_{\mathbb{R}} W_g f(x,s) T_x D_s \gamma \, \frac{dxds}{s^2} = C_{g,\gamma} f,$$

where the equality is understood in a vector-valued weak sense (see Daubechies [2] and Gröchenig [5]). The convergence of this integral is an important problem. In fact, there are several results on the convergence of the inverse continuous or discrete wavelet transform (see e.g. [1, 7–9, 13–15, 11, 12]). In this paper we summarize the results about the convergence of

$$\lim_{S\to 0, T\to\infty} \int_{S\le |s| \le T} \int_{\mathbb{R}} W_g f(x,s) T_x D_s \gamma \, \frac{dxds}{s^2}$$

including the case when $T = \infty$.

In the proof of these results, we use summability theory, more exactly, a general method of summation, the so called θ-summation method, which is generated by a single function θ. The means generated by the θ-summation are defined by

$$\sigma_T^\theta f(x) := \int_{\mathbb{R}} \theta\left(\frac{-t}{T}\right) \widehat{f}(t) e^{2\pi \imath x t} \, dt.$$

In Feichtinger and Weisz [3, 4] we have proved that under some conditions of the Fourier transform of θ, the θ-means $\sigma_T^\theta f$ converge to f almost everywhere or at Lebesgue points and in norm as $T \to \infty$, whenever f is in the $L_p(\mathbb{R})$ space or in a Wiener amalgam space.

* This research was supported by the Hungarian Scientific Research Funds (OTKA) No K115804.

References

1. R. Ashurov. Convergence of the continuous wavelet transforms on the entire Lebesgue set of L_p-functions. *Int. J. Wavelets Multiresolut. Inf. Process.*, 9:675–683, 2011.
2. I. Daubechies. *Ten Lectures on Wavelets*. SIAM, Philadelphia, 1992.
3. H. G. Feichtinger and F. Weisz. The Segal algebra $\mathbf{S}_0(\mathbb{R}^d)$ and norm summability of Fourier series and Fourier transforms. *Monatsh. Math.*, 148:333–349, 2006.
4. H. G. Feichtinger and F. Weisz. Wiener amalgams and pointwise summability of Fourier transforms and Fourier series. *Math. Proc. Cambridge Philos. Soc.*, 140:509–536, 2006.
5. K. Gröchenig. *Foundations of Time-Frequency Analysis*. Birkhäuser, Boston, 2001.
6. E. Hernández and G. Weiss. *A First Course on Wavelets*. CRC Press, 1996.
7. S. E. Kelly, M. A. Kon, and L. A. Raphael. Local convergence for wavelet expansions. *J. Func. Anal.*, 126:102–138, 1994.
8. K. Li and W. Sun. Pointwise convergence of the Calderon reproducing formula. *J. Fourier Anal. Appl.*, 18:439–455, 2012.
9. M. Rao, H. Sikic, and R. Song. Application of Carleson's theorem to wavelet inversion. *Control Cybern.*, 23:761–771, 1994.
10. D. F. Walnut. *An Introduction to Wavelet Analysis.* Basel: Birkhäuser, 2002.
11. F. Weisz. Inversion formulas for the continuous wavelet transform. *Acta Math. Hungar.*, 138:237–258, 2013.
12. F. Weisz. Inverse continuous wavelet transform in Pringsheim's sense on Wiener amalgam spaces. *Acta Math. Hungar.*, 145:392–415, 2015.
13. M. Wilson. *Weighted Littlewood-Paley Theory and Exponential-Square Integrability*, volume 1924 of *Lecture Notes in Mathematics*. Springer, Berlin, 2008.
14. M. Wilson. How fast and in what sense(s) does the Calderon reproducing formula converge? *J. Fourier Anal. Appl.*, 16:768–785, 2010.
15. A. Zayed. Pointwise convergence of a class of non-orthogonal wavelet expansions. *Proc. Am. Math. Soc.*, 128:3629–3637, 2000.

Analysis of Patterns with the Reed-Muller-Fourier Transform

[1]Claudio Moraga, [2]Radomir S. Stanković

[1]Faculty of Computer Science, TU Dortmund University, 44221 Dortmund, Germany
Dept. of Computer Science, Faculty of Electronic Engineering, 18000 Niš, Serbia
Claudio.Moraga@tu-dortmund.de, Radomir.Stankovic@gmail.com

Extended Abstract

Let Γ be a finite ordered set of colors with cardinality p, and Z_p the ring of integers modulo p, $(Z_p, \oplus, \cdot)$. Let $\beta : \Gamma \to Z_p$ be a bijection assigning an element of Z_p to each color in such a way that the ordering of the colors is preserved. Pixels are atoms of a picture and carry a single color. (The size of a pixel is defined according to requirements of geometric and chromatic resolution for a picture under consideration.) A pattern is an array of pixels. In this paper, a pattern is also a matrix with entries from Z_p obtained by applying β to every pixel of a picture. Operations among patterns are conducted on the corresponding matrices. Pattern attributes associated to a matrix are understood as attributes of the pattern represented by such a matrix.

In what follows, some properties of patterns will be studied in a transform domain. In this paper, we select the Reed-Muller-Fourier (RMF) transform [1], [2]. It is known that this transform matrix is lower triangular, self-inverse and has a Kronecker product structure [3]. Moreover, this transform is based on the Gibbs convolutional product [4]. Fig. 1 shows the basic transform matrices for $p = 3, 4$, and 5 as will be used in this paper.

$$\mathbf{R}_3(1) = \begin{bmatrix} 1&0&0 \\ 1&2&0 \\ 1&1&1 \end{bmatrix} \quad \mathbf{R}_4(1) = \begin{bmatrix} 1&0&0&0 \\ 1&3&0&0 \\ 1&2&1&0 \\ 1&1&3&3 \end{bmatrix} \quad \mathbf{R}_5(1) = \begin{bmatrix} 1&0&0&0&0 \\ 1&4&0&0&0 \\ 1&3&1&0&0 \\ 1&2&3&4&0 \\ 1&1&1&1&1 \end{bmatrix}$$

Fig. 1. RMF transform matrices for $p = 3, 4$, and 5.

The following notation will be used in the rest of the paper: $\mathbf{A}(n)$ will denote a $(p^n \times p^n)$ matrix (and pattern). $\mathbf{A}(n, m)$ will denote a $(p^n \times p^m)$ matrix (and pattern). For the RMF-transform matrix, the notation $\mathbf{R}(n)$ will be used. $Ones(n)$ represents a matrix with all entries equal to 1. $Zeroes(n)$ is a matrix with all entries equal to 0. $Single(n)$ represents a matrix with all entries equal to 0, except for the element at the left upper corner, which is equal to 1. For the analysis of patterns, a two-sided RMF-transform will be used (see definition below), the transformed pattern will be called "spectrum" and will be identified by Σ. Unless otherwise specified, all operations will be done in the ring $(Z_p, \oplus, \cdot)$.

Definition 1 *Given a pattern $A(n,m)$, its spectrum $\Sigma_A(n,m)$, is calculated as*

$$\Sigma_A(n,m) = \mathbf{R}(n) \cdot \mathbf{A}(n,m) \cdot (\mathbf{R}(m))^T,$$

and

$$\mathbf{A}(n,m) = \mathbf{R}(n) \cdot \Sigma_A(n,m) \cdot (\mathbf{R}(m))^T,$$

where T denotes the matrix transpose.

Lemma 1 *(Proofs will be given in the full paper)*
If $\mathbf{C}(n,m) = \mathbf{A}(n,m) \oplus \mathbf{B}(n,m)$ then $\Sigma_C(n,m) = \Sigma_A(n,m) \oplus \Sigma_B(n,m)$.

Lemma 2 *If $\mathbf{C}(n+r, m+s) = \mathbf{A}(n,m) \otimes \mathbf{B}(r,s)$ then $\Sigma_C(n+r, m+s) = \Sigma_A(n,m) \otimes \Sigma_B(r,s)$.*

Lemma 3 $\Sigma_{Ones}(n,m) = Single(n,m)$ *and* $\Sigma_{Single}(n,m) = Ones(n,m)$.

Remark 1 *The Lemma 3 is a two-dimensional extension of the Fourier transform of an impulse. This property is not preserved if a number theoretic transform based on Fermat primes is used [5].*

Lemma 4 *Let $J(n)$ denote the pattern with 1s along the diagonal with positive slope and all other entries are equal to 0. If p is a prime, then this pattern is a fixpoint of the transform, i.e., $\Sigma_J(n) = J(n)$.*

Definition 2 *A mosaic is the Kronecker product of $Ones(n,m)$ and a seed $\mathbf{D}(r,s)$.*

Example 1 *Let $\mathbf{M}$ denote a mosaic $\mathbf{M}(2+r, 3+s) = Ones(2,3) \otimes \mathbf{D}(r,s)$. From lemmas 2 and 3 given above,*

$$\Sigma_M = \Sigma_{Ones}(2,3) \otimes \Sigma_D(r,s) = Single(2,3) \otimes \Sigma_D(r,s).$$

It follows that Σ_M is a $(p^{2+r} \times p^{3+s})$ block matrix, where the left upper block represents the spectrum of the seed $\mathbf{D}$, and all other blocks are $Zeroes(r,s)$ matrices.

It is simple to see that if the original mosaic becomes a single noisy pixel, it will no longer be a proper mosaic and several, if not all, original $Zeroes$ matrices will be contaminated. The effect of noise will be detected. Other properties of patterns, such as symmetry, chroma-shifting, folding and mirroring will be studied in the full paper.

References

1. Stanković, R.S., Some remarks on Fourier transforms and differential operators for digital functions, *Proc. 22nd Int. Symp. on Multiple-valued Logic*, Sendai, Japan, 365-370. IEEE Press N.Y., 1992.
2. Stanković, R.S., Stanković, M., Moraga, C., Sasao, T., Calculation of Reed-Muller-Fourier coefficients of multiple-valued functions through multiple place decision diagrams. *Proc. 24th Int. Symp. on Multiple-valued Logic*, 82-88. IEEE Press N.Y., 1994.
3. Stanković R.S., Stanković M., Moraga C., The Pascal triangle (1654), the Reed- Muller-Fourier Transform (1992), and the Discrete Pascal Transform (2005). In *Proc. 46th Int. Symp. on Multiple-valued Logic*, 229-234. IEEE Press N.Y., 2016
4. Gibbs, J.E.: Instant Fourier transform, *Electronics Letters*, Vol. 13, No.5, 122-123, 1977.
5. Moraga C., Pattern Analysis under Number Theoretic Transforms. *LNCS 6928*, 280-287, 2012.

Remarks on Permutation Matrices Related to Gibbs Characterization of Bent Functions

[1]Radomir S. Stanković, [1]Milena Stanković,
[2]Jaakko T. Astola, [3]Claudio Moraga,

[1]Dept. of Computer Science, Faculty of Electronic Engineering, Niš, Serbia
[2]Dept. of Signal Processing, Tampere University of Technology, Tampere, Finland
[3] Technical University of Dortmund, 44221 Dortmund, Germany

Key words: Bent functions, Walsh functions, Dyadic derivatives, GPU computing.

Bent functions are a particular class Boolean functions with applications in coding theory, cryptography, spread spectrum communications, and some other areas [1]. They are defined as functions satisfying the perfect nonlinearity criterion, which in the spectral domain can be expressed as the requirement for the flat Walsh spectrum in $(0,1) \to (1,-1)$ encoding. The term flat means that for a given function f all its Walsh spectral coefficients S_f have the same absolute value equal to $2^{n/2}$. In the considered encoding, Walsh spectra of Boolean functions must have the sum of Walsh coefficients equal $\pm 2^n$. For bent functions, this requirement implies a restriction to the number of positive and negative values in the functions vector. For example, for $n = 4$, the number of negative values in the function and the Walsh spectrum can be either 6 or 10. This property is related to the characterization of bent functions in terms of the Gibbs dyadic derivatives [4] that is considered in the present paper.

The Gibbs dyadic derivative is defined as an operator sharing many of properties of the Newton-Leibniz derivative but acting on functions in binary (logic) variables [2]. It is defined as an operator having the discrete Walsh functions as eigenfunctions and elements of the sequence $G = \{0, 1, \ldots, 2^n - 1\}$, n is the number of binary variables, as eigenvalues [2]. For a Boolean function f, the Gibbs dyadic derivative can be expressed as a vector $\mathbf{D}_f$ of integer values whose elements d_i, $i = 0, 1, \ldots, 2^n - 1$, are called the Gibbs coefficients.

In the Gibbs derivative of a bent function, the coefficients with the negative values appear at the same positions as the negative values in the function vector. Therefore, the number of negative values in the function is the same as in the Gibbs derivative, which is not necessarily the case in the Walsh spectrum.

For bent functions, the Gibbs coefficients are mutually different and their absolute values are equal to the eigenvalues of the Gibbs derivative. It is important to notice that for a bent function all the eigenvalues should appear as its Gibbs coefficients. For other Boolean functions this is not the case. Therefore, for two bent functions, the Gibbs dyadic derivative differ just in the order of Gibbs coefficients.

Example 1 *Consider the bent function specified by the function vector in* $(0,1) \to (1,-1)$ *encoding as* $\mathbf{F} = [-1, 1, 1, 1, 1, 1, 1, -1, -1, 1, -1, -1, 1, 1, -1, 1]^T$. *The*

Walsh spectrum $\mathbf{S}_f = [4, -4, 4, -4, -4, -4, -4, -4, 4, 4, -4, -4, 4, -4, -4, 4]^T$ *is flat, and its Gibbs derivative takes all eigenvalues with* 6 *negative Gibbs coefficients at the same positions as negative function values in the function vector* $\mathbf{D}_f = [-7, 1, 10, 12, 4, 2, 9, -15, -5, 3, -8, -14, 6, 0, -11, 13]^T$*, and* 10 *negative values in the Walsh spectrum at different positions. The sum of absolute values is equal* 60 *for both positive and negative Gibbs coefficients.*

There cannot be bent functions with the same order of absolute values of Gibbs coefficients except the function f and its logic complement $\overline{f} = f \oplus 1$. The pairs of bent functions $(f, \overline{f})$ share the Gibbs derivative with the same order of Gibbs coefficients, but with opposite signs.

Remark 1 *Bent functions are uniquely characterized, up to their logic complements, by the permutations of their Gibbs coefficients.*

The permutations are not arbitrary, the structure of the permutation matrices $\mathbf{P} = [p_{i,j}]$ assigned to the Gibbs derivatives of bent function reflects the structure of the Gibbs matrix that defines the Gibbs differentiator as a linear, singular, but invertible operator [2], [3], [5]. The appearance of non-zero values in $\mathbf{P}$ is determined in terms of the values of Gibbs coefficients and the cyclic shift of the function $\delta = [1, 0, \ldots, 0]^T$. Another condition comes from the assignment of positive and negative signs to the Gibbs coefficients. It is required that the Gibbs coefficients can be permuted in such a way that the absolute values of the sums of Gibbs coefficients with positive and negative values have to be exactly $2^{(n-2)} \cdot 2^n - 1$. This does not hold for functions that are not bent. From these requirements it follows a specific block structure of permutation matrices appearing in Gibbs characterization of bent functions that is the subject of study in the present paper. The considerations are restricted on an analysis of all 896 bent functions of four variables and subsets of bent functions for $n = 6$ and $n = 8$.

References

1. Cusick, T.W., Stănică, P., *Cryptographic Boolean Functions and Applications*, Academic Press/Elsevier, 2009.
2. Gibbs, J.E., "Walsh spectrometry, a form of spectral analysis well suited to binary digital computation", *Nat. Phys. Lab.*, Teddington, Middx, UK, 1967, 24pp.
3. Pichler, F., "Walsh functions and linear system theory", Technical Research Report, T-70-05, Dept. of Electrical Engineering, University of Maryland, College Park, Maryland 20742, April 1970, ii+46.
4. Stankovicć, R.S., Astola, J.T., Moraga, C., Gajić, D., "Remarks on characterization of bent functions in terms of Gibbs dyadic derivatives", in Moreno-Diaz, R., Pichler, F., Quesada, A., (eds.) *EUROCAST 2015*, LNCS 9520, 2015, 632-639.
5. Stanković, R.S., Butzer, P.L., Schipp, F., Wade, W.R., Su, W., Endow, Y., Fridli, S., Golubov, B.I., Pichler, F., Onnewerr, K.C.W., *Dyadic Walsh Analysis from 1924 Onwards, Walsh-Gibbs-Butzer Dyadic Differentiation in Science, Volume 1, Foundations, A Monograph Based on Articles of the Founding Authors, Reproduced in Full*, Atlantis Press, Atlantis Studies in Mathematics for Engineering and Science, 2015, ISBN 978-94-6239-162-8, ISBN 978-94-6239-163-5 (eBook).

New Spectral Invariant Operations for Functions with Disjoint Products in the Polynomial Form

[1]Milena Stanković, [2]Claudio Moraga, [1]Radomir S. Stanković,

[1]Dept. of Computer Science, Faculty of Electronic Engineering, Niš, Serbia
[2] Technical University of Dortmund, 44221 Dortmund, Germany

Key words: Invariant operations, Walsh spectrum

It has long been known that some transformations of a binary function has the effect of only a permutation of some coefficients in the Walsh-Hadamard spectrum or just change the sign of some coefficients. Those operations are known as invariant operations in the Walsh-Hadamard domain, [2]. We first present the definition of the Walsh-Hadamard spectrum, [3].

Definition 1 *Walsh spectrum*
The Walsh Hadamard spectrum $\mathbf{S}_f(n)$ *of the binary function* $f(x_1, x_2, \cdots, x_n)$ *of* n *variables is defined as:*

$$\mathbf{S}_f(n) = \mathbf{W}(1)^{\otimes n}\mathbf{F}(n) \tag{1}$$

where $\mathbf{W}(1) = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$ *and* $\mathbf{F}(n)$ *is the truth vector of the function* f *in* $(1, -1)$ *coding.*

$\mathbf{S}_f(n)$ is a vector of 2^n coefficients. Here we will use a notation of the coefficients in the spectrum with a binary subscripts $S_{b_1,b_2,\cdots,b_n}$ where $b_i \in (0,1), i = 1, 2, \cdots, n$: $\mathbf{S}_f(n) = [S_{00\ldots0}, S_{00\ldots1}, \cdots, S_{11\ldots1}]$.

There are five invariant operations in the Walsh-Hadamard domain known as: complement of the function, complement of the input variable, permutation of two input variables, linear translation and disjoint linear translation. Those operations have beed used for spectral classification and carracterisation of some classe sof Boolean functions, [2], [1]. Here will be shown some new operations defined for the functions with $n \geq 5$ variables, which have disjoint products of two variables in their polynomial forms. As result of these new operations only the values of some spectral coefficients will by permuted, like in case of the known invariant operations.

Theorem 1 *Modification of a binary function* f *with an odd number of input variables* $n = 2 * k + 1$ $(k \geq 2)$*, witch has a sum of disjoint products of two variables in its polynomial form:*

$$f(x_1, x_2, \cdots, x_n) = x_{i_1}x_{i_2} \oplus x_{i_3}x_{i_4},$$

where $(i_1, i_2) \cap (i_3, i_4) = \phi$*, into a function* $g = f \oplus x_{j_1}x_{j_2}x_{j_3}$ *where* $j_1 \in (i_1, i_2)$*,* $j_2 \in (i_3, i_4)$ *and* $j_3 \notin (i_1, i_2, i_3, i_4)$ *results in the permiutation of the following pairs of spectral coefficients:*

$$S_{g_{b_1,\cdots,b_{j_4}=1,b_{j_5}=1,b_{j_3}=0,\cdots,b_n}} \leftrightarrow S_{f_{b_1,\cdots,b_{j_4}=1,b_{j_5}=1,b_{j_3}=1,\cdots,b_n}}$$

where $j_4 = \{i_1, i_2\} \setminus j_1$ *and* $j_5 = \{i_3, i_4\} \setminus j_2$

All coefficients with $b_{j_4} = b_{j_5} = 1$, *and* $b_{j_3} = 0$ *in the subscripts will be permuted with the coefficients with* $b_{j_4} = b_{j_5} = 1$, *and* $b_{j_3} = 1$ *in the subscripts.*

Proof of the Theorem 1 will be given in the full paper.

Example 1 *The function* $f(x_1, x_2, \cdots, , x_5) = x_1x_2 \oplus x_3x_4$ *has the spectrum* $\mathbf{S_f} = [8, 0, 8, 0, 8, 0, -8, 0, 8, 0, 8, 0, 8, 0, -8, 0, 8, 0, 8, 0, 8, 0, -8, 0, -8, 0, -8, 0, -8, 0, 8, 0]^T$, *while the function* $g(x_1, x_2, \cdots, x_5) = f \oplus x_1x_3x_5$ *the spectrum* $\mathbf{S}_g = [8, 0, 8, 0, 8, 0, -8, 0, 8, 0, 0, 8, 8, 0, 0, -8, 8, 0, 8, 0, 8, 0, -8, 0, -8, 0, 0, -8, -8, 0, 0, 8]^T$. *In this case the following pairs of coefficients are permuted:*

$$S_{g_{b_1,b_2=1,b_3,b_4=1,b_5=0}} \leftrightarrow S_{f_{b_1,b_2=1,b_3,b_4=1,b_5=1}}$$

for $b_1, b_3 \in (0, 1)$,

Theorem 2 *Modification of a binary function* $f(x_1, x_2, \cdots, x_n)$ *with an even number of input variables* $n = 2 * k$ $(k \geq 3)$, *witch has a sum of disjoint products of two variables in its polynomial expression:* $f(x_1, x_2, \cdots, x_{2*k}) = x_{i_1}x_{i_2} \oplus x_{i_3}x_{i_4} \oplus x_{i_5}x_{i_6}$, *where* $(i_1, i_2) \cap (i_3, i_4) \cap (i_5, i_6) = \phi$, *into a function* $g(x_1, x_2, \cdots, x_n) = f \oplus x_{j_1}x_{j_2}x_{j_3}$ *where* $j_1 \in (i_1, i_2)$, $j_2 \in (i_3, i_4)$ *and* $j_3 \in (i_5, i_6,)$; *this operation results in the interchange of the following pairs of spectral coefficients:*

$$S_{g_{\cdots,b_{j_4}=1,b_{j_5}=1,b_{j_3}=1,\cdots}} \leftrightarrow S_{f_{\cdots,b_{j_4}=1,b_{j_5}=1,b_{j_3}=0,\cdots}}.$$

Proof of the Theorem 2 will be given in the full paper.

Example 2 *Consider the function* $f(x_1, x_2, \cdots, x_6) = x_1x_2 \oplus x_3x_4 \oplus x_5x_6$ *and the function* $g(x_1, x_2, \cdots, x_6) = f \oplus x_1x_3x_5$. *In this case the following pairs of spectral coefficients will be permuted:* $S_{g_{20}} \leftrightarrow S_{f_{22}}$, $S_{g_{21}} \leftrightarrow S_{f_{23}}$, $S_{g_{28}} \leftrightarrow S_{f_{30}}$, $S_{g_{29}} \leftrightarrow S_{f_{31}}$, $S_{g_{52}} \leftrightarrow S_{f_{54}}$, $S_{g_{53}} \leftrightarrow S_{f_{55}}$, $S_{g_{60}} \leftrightarrow S_{f_{62}}$, *and* $S_{g_{61}} \leftrightarrow S_{f_{63}}$.

Invariant operations, which introduce the possibility to add a lager product to the sum of disjoint products of two variables are important in the context of carracterisation of bent functions, [4].

References

1. Edwards, C.R., "The application of the Rademacher-Walsh transform to Boolean function classification and threshold logic synthesis", Trans. IEEE C24, 48-62, June 1975.
2. Hurst, S. L., *The Logical Processing of Digital Sygnals*, Crane, Russak & Company, Inc., New York, Edward Arnold, London, 1978.
3. Karpovsky, M., Stankovic, R., S., Astola, J., *Spectral Logic and Its Applications for the Design of Digital Devices*, Wiley, 2008.
4. Qu, C., Seberry, J., Pieprzyk, J., *A construction of hyperbent functions with polynomial trace form*, Discrete Applied Mathematics 102 (2000) 133-139.

DetectionEvaluationJ: a tool for measuring the goodness of object detection algorithms*

C. Domínguez, M. García, J. Heras, A. Inés, E. Mata, and V. Pascual

Department of Mathematics and Computer Science of University of La Rioja, Spain
{cesar.dominguez, manuel.garciad, jonathan.heras, adrian.ines, eloy.mata, vico.pascual}@unirioja.es

1 Extended abstract

Object detection algorithms are applied in diverse computer vision applications; for instance, surveillance, traffic monitoring or melanoma detection. Recent advances in this area have been leaded by the availability of open-source datasets (e.g. the PASCAL VOC 2012 [1], the MS COCO datasets [2], or the ILSVRC competition [3]) and the application of deep learning techniques [5].

In order to evaluate the quality of object detection algorithms, the regions of interest (ROIs) located by such algorithms are compared against the regions manually annotated by experts (such regions are known as the *gold standard* or *ground truth*) using different metrics. Some of the most widely employed measures in this context are the area of intersection-over-union between two detections [1], and pixel-level specificity, precision, and recall [7].

Since the task of comparing the detected regions against a gold standard is necessary to measure the quality of object detection algorithms, we have developed a tool, called *DetectionEvaluationJ*, that facilitates such a process and avoids reinventing the wheel. DetectionEvaluationJ is an ImageJ plugin [4] that has been designed to evaluate the goodness of object detection algorithms using several metrics. DetectionEvaluationJ takes as input a set of images, the gold standard associated with such images, and the detected regions obtained by the detection algorithm; and, it generates as output a report that summarises the quality of the detection algorithm based on the available measures. This workflow is depicted in Figure 1.

DetectionEvaluationJ can handle different kinds of regions (including rectangles, circles, polygons, points, and other geometrical figures) both for the gold standard and the detected regions. Such regions can be loaded in DetectionEvaluationJ using either the internal representation employed in ImageJ or a new format called ROIXML. The ROIXML format is based on the XML format and is therefore independent of any particular computer system and extensible for future needs. The structure of XML files following the ROIXML format is fixed by an XML schema, that not only determines the structure of XML files but also specifies and restricts the content of their elements. This schema has been developed taking into account the information that is needed to encode different

* Supported by Ministerio de Educación y Ciencia, project MTM2014-54151-P

kinds of ROIs. The ROIXML format simplifies interoperability since it allows users from systems like OpenCV or Matlab to generate files that can be read by DetectionEvaluationJ.

Once the gold standard and the detected regions are loaded in DetectionEvaluationJ, the user can measure how good are the detected regions using the following pixel-level metrics: area of intersection-over-union, accuracy, precision, recall, fallout, sensitivity, specificity, negative predictive value, false discovery rate, false negative rate, LR+, LR-, and F-measure ($\alpha = 0.5, 1$ and 2). In addition, the user can load the output of several detection algorithms and compare their quality using the aforementioned metrics and the ROC space. Analogously, this plugin can also be applied to study inter-rater agreement among experts [6].

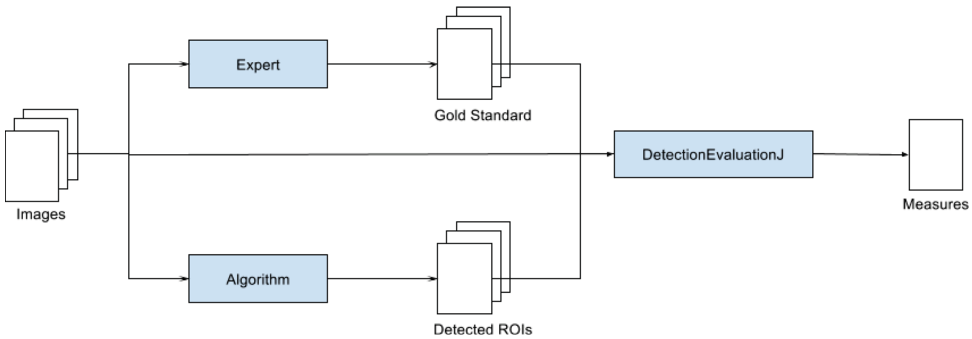


Fig. 1. Workflow of DetectionEvaluationJ

DetectionEvaluationJ is available at joheras.github.io/DetectionEvaluationJ/ together with the installation instructions and usage examples.

References

1. M. Everingham et al. The PASCAL Visual Object Classes Challenge 2012 (VOC2012) Results, 2012. http://www.pascal-network.org/challenges/VOC/voc2012/workshop/index.html.
2. T.-Y. Lin et al. Microsoft COCO: Common Objects in Context. In *European Conference on Computer Vision*, 2014.
3. O. Russakovsky et al. ImageNet Large Scale Visual Recognition Challenge. *International Journal of Computer Vision (IJCV)*, 115(3):211–252, 2015.
4. C. A. Schneider, W. S. Rasband, and K. W. Eliceiri. NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, 9(7):671–675, 2012.
5. R. Shaoqing et al. Faster R-CNN: Towards real-time object detection with region proposal networks. *arXiv preprint arXiv:1506.01497*, 2015.
6. J. S. Silva et al. Algorithm Versus Physicians Variability Evaluation in the Cardiac Chambers Extraction. *IEEE Transactions on Information Technology in Biomedicine*, 16(5):835–841, 2012.
7. C. Wolf and J. M. Jolion. Object count/area graphs for the evaluation of object detection and segmentation algorithms. *International Journal of Document Analysis and Recognition*, 8:280–296, 2006.

Evaluation of whole-image descriptors for metric localization

Manuel Lopez-Antequera[1,2], Javier Gonzalez-Jimenez[1] and Nicolai Petkov[2]

[1] Machine Perception and Intelligent Robotics (MAPIR). Dept. Ingeniería de Sistemas y Automática. Instituto de Investigación Biomédica de Málaga, Universidad de Málaga. Spain.
`mapir.isa.uma.es` — `(mlopezantequera/javiergonzalez)@uma.es`
[2] Johann Bernoulli Institute of Mathematics and Computing Science, University of Groningen, The Netherlands
`www.cs.rug.nl/is` — `(m.a.lopez.antequera/n.petkov)@rug.nl`

Extended abstract for initial submission

Image-based localization is the task of recovering the pose (position and orientation) of a camera. It is of great interest in applications where GPS is unavailable or imprecise, such as in urban environments or indoor settings. This task is often regarded as a nearest-neighbor search, also known as place recognition, where the pose space is represented by a set of discrete locations. Although efficient solutions exist for this discretization, the general case of localizing in continuous space without the use of local keypoints remains a challenge. Describing images using holistic (whole-image) descriptors is the standard practise for topological localization ("*in which place is the image?*"). However, holistic descriptors can also be used for metric localization ("*what is the pose where the image has been taken from?*").

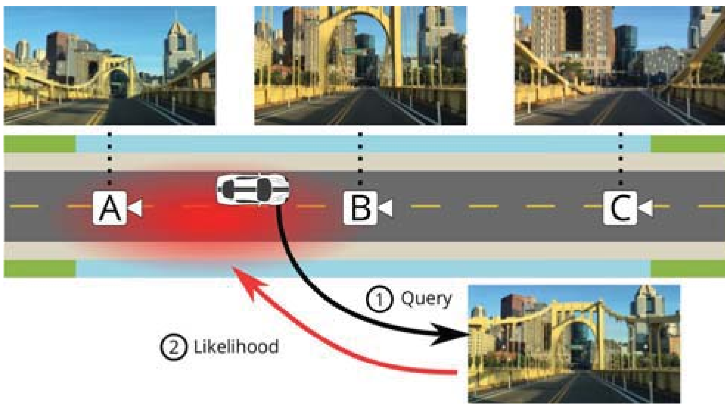


Fig. 1. The appearance of the query image suggests that it is located somewhere between images A and B. State of the art holistic descriptors present smooth changes in their values with changes in camera pose and can be used to localize on a finer grain than nearest-neighbor approaches.

We study the general case of metric localization (fig. 1), in which there are no restrictions on the position of the camera. Instead of selecting the best location from a grid, graph or collection of known images, any point in the pose space can be selected as the estimate.

Performing continuous metric localization without local keypoints is challenging, however, it has shown promising results in previous work: in [1], the authors use global Fourier descriptors on omnidirectional images, performing regression through a Gaussian process and representing the location of the camera by a particle filter. Recently, we [2] performed localization through appearance regression, using a convolutional neural network-based descriptor trained for place recognition as the image representation. These results indicate that metric localization through appearance regression is feasible and merits further research.

In this paper, we analyze the current state of the art in convolutional neural network-based holistic descriptors with respect to their applicability for metric localization through appearance regression and discuss the desired characteristics of a whole-image descriptor for their use in such systems. First, we will describe the components of such a localization system in order to establish a framework. We then examine the behaviour of several state-of-the-art convolutional neural network-based holistic descriptors in search for proportionality and smoothness in the change of their values with respect to camera motion, and compare them according to their behaviour and their use of computational resources.

Fig. 2. Original (left) and synthesized images yielding similar descriptors.

Finally, we leverage recent advances in image synthesis to invert the representations extracted using these descriptors, in order to understand what visual characteristics are being modelled by them (fig. 2). Specifically, we generate images using a generative adversarial network as shown in [3]. Our findings indicate that descriptors trained to perform place recognition through weakly supervised approaches are better suited for this task than generic internal representations of networks trained to perform object recognition, while also being much less demanding on memory and compute time.

References

1. Huhle, B., Schairer, T., Schilling, A., Straßer, W.: Learning to localize with Gaussian process regression on omnidirectional image data. In: Intell. Robot. Syst. (IROS), 2010 IEEE/RSJ Int. Conf. (2010) 2
2. Lopez-Antequera, M., Petkov, N., Gonzalez-Jimenez, J.: Image-based localization using Gaussian processes. In: Indoor Position. Indoor Navig. (IPIN), 2016 Int. Conf. (2016) 2
3. Nguyen, A., Dosovitskiy, A., Yosinski, J., Brox, T., Clune, J.: Synthesizing the preferred inputs for neurons in neural networks via deep generator networks. In: Adv. Neural Inf. Process. Syst. 29 (2016) 2

Filtering and Segmentation of Retinal OCT Images

Miguel Alemán-Flores[1] and Rafael Alemán-Flores[2]

[1] Departamento de Informática y Sistemas
Universidad de Las Palmas de Gran Canaria, Spain
[2] Departamento de Morfología
Universidad de Las Palmas de Gran Canaria, Spain

Extended Abstract

OCT (Optical Coherence Tomography) is an image modality that has important applications in several medical fields, such as ophthalmology, dermatology or cardiology. In this work, we focus on retinal OCT, which provides cross-sectional images of the retina and is widely used for the diagnosis and monitoring of different pathologies. Most OCT units provide some automatic processing of the acquired images. However, the high rate of noise and the heterogeneity of the retinal layers limit the possibilities of an automatic or semi-automatic analysis of the images.

In this work, we propose a method to filter the images and obtain well-defined regions in the retinal OCT slices, as illustrated in Fig. 1. An initial noise-reduction stage consists in the application of an anisotropic filter based on [1], in which diffusion is not homogeneously performed in order to preserve the boundaries of the regions. When the layers in the tomography are close enough, this filter can be extended to three dimensions by considering the neighbors in the previous and following layers.

Once the images have been filtered, the region of interest is delimited by extracting the upper and lower limits of the retina in each slice. Afterward, the selected region in each cross-sectional image is quantized by concentrating the intensity values around those reference values that best represent the different layers. A variation of the heat equation using an external term is applied in order to homogenize the regions while the different pixels converge to their corresponding representatives [2]. This requires fixing a series of concentration values (final values in the image) and their corresponding attraction ranges (intervals that converge toward those values). These values are obtained from the histogram of the image. Finally, a statistical process is performed to refine the result by considering the neighborhood of each pixel.

From the contours of the regions that have been extracted in the different slices of the tomography, a three-dimensional reconstruction of the retina can be obtained, so that it is possible to study its shape, extract measurements or perform any other further analysis.

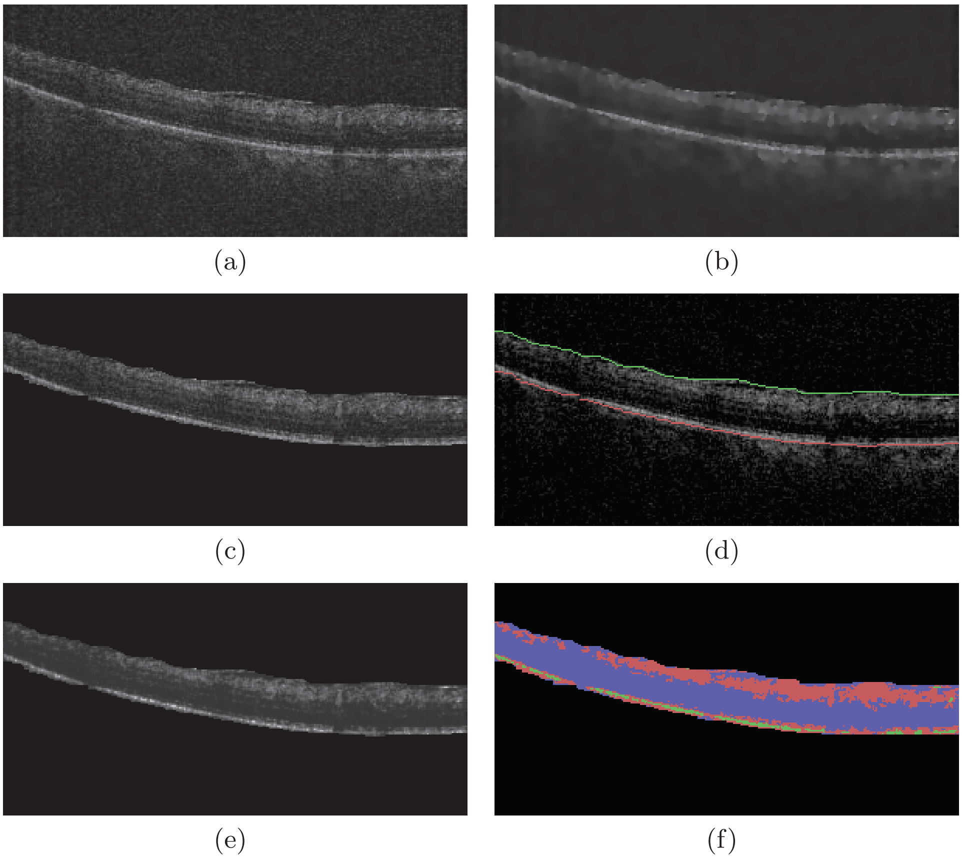


Fig. 1. Stages of the segmentation: (a) Original image, (b) Filtered image using anisotropic diffusion, (c) Extraction of the region of interest, (d) Limits of the retina, (e) Image quantization, and (f) Region labeling.

References

1. Perona, P., Malik, J.: Scale-Space and Edge Detection Using Anisotropic Diffusion. IEEE Transactions on Pattern Analysis and Machine Intelligence 12(7), 629-639 (1990)
2. Álvarez, L., Mazorra, L.: Signal and Image Restoration Using Shock Filters and Anisotropic Diffusion. SIAM J. Numer. Anal. 31(2), 590-605 (1994)

Towards Egocentric Sentiment Analysis

Estefania Talavera, Petia Radeva, and Nicolai Petkov

University of Barcelona, Spain, and University of Groningen, The Netherlands
e.talavera.martinez@rug.nl,petia.ivanova@ub.edu,n.petkov@rug.nl

Abstract. Nowadays, the use and availability of egocentric data are fastly increasing due to the growing use of wearable cameras. Given egocentric photo streams capturing the wearer's days, we propose a method that aims to assign sentiment to events extracted from egocentric images. Such moments could be used in several ways as for example, being candidates to be worth to retrieve according to their possibility of representing a positive experience for the camera wearer.

Keywords: egocentric images, moment retrieval, sentiment analysis

1 Introduction

Life-logging describes an ego-centric vision of the experiences of a person. This work is a preliminary study towards assignment of sentiment analysis to life-logging photo streams. We want to predict what a sentiment an observer would assign to an egocentric event. The aim is to seek the comforting moments with high possibility of retrieving a memorable-positive feeling to the user. To the best of our knowledge none of the previous approaches has dealt with this problem.

2 Approach

Fig. 1. Images labelled as Positive (green), Neutral (yellow) and Negative (red).

Given a photo stream, we apply a temporal segmentation based on the work presented in [1]. We consider an event as a group of images representing the same scene. We rely on semantic information extracted from the images for the classification. For that purpose, we use the DeepSenti Network[2], which is based on the Visual Sentiment Ontology (VSO)[3]. The network extracts semantic concepts called Adjective Noun Pairs (ANP), which are composed by a pair of a noun and an adjective with a given sentiment value in the range of [-2 : 2]. The fact that the ANPs are classified strictly into Negative or Positive concepts could be a limitation when aiming to recognize sentiments from daily moments, since most of them used to be neutral. We propose a method that takes into account the sentiment associated to the ANPs describing the images, and the sentiment associated to the nouns that compose those concepts. To find the relevant ANPs for an event we propose a new method of filtering based on conceptual concepts. To do so, we used the wordNet tool (http://wordnet.princeton.edu) to extract the semantic similarity between concepts. Then we use that information to cluster them. As further step, following what would be considered as similar from an ego-centric point of view, we manually refine the resulted clusters into 44 categories. We label the clusters as Positive, Neutral or Negative. First, we extract the ANPs of each event frame and rank them by their probability ($Prob_{ANP_j}$) of describing an image and select the top-5 ANPs. Then, we cluster them based on their Wordnet-based nouns semantic distance. For the event sentiment computation (S_{event}), we focus on the largest cluster. We fuse the contribution of the ANPs and the nouns extracted following the eq. 1. We take into account the probability associated to the ANPs aiming to penalize the ANPs with low relation to the image content:

$$S_{event} = \sum_j (\alpha * S_{ANP_j} + \beta * S_{Noun_j}), j = 1 : N_{ANP}, \tag{1}$$

where $S_{ANP_j} = (S^{VSO}_{ANP_j} * Prob_{ANP_j})$, $S^{VSO}_{ANP_j}$ is the ANP's sentiment given by the VSO and S_{Noun} is the label of the noun, α and β are the contributions (%) of the ANPs and the nouns.

3 Validation

Data set: We created the UBRUG-Senti dataset, which is composed by 4495 ego-centric photos recorded with a Narrative Clip camera, with a frequency of 2fpm (http://getnarrative.com/). These photos compound 98 events that were manually labelled as Positive (36), Neutral (43) and Negative (19) events.

Results: We run experiments with different combinations of α and β values. We performed a balanced 5-fold cross validation. We achieved an average training accuracy of 73±3.8% and F-score of 59±5.4% and test accuracy of 75±8.2% and F-score of 61±13.2%, when $\alpha = 0.8$ and $\beta = 0.2$, i.e. when the ANP information is considered but the major contribution comes from the noun sentiment associated. As expected, neutral events are the most challenging ones to classify.

4 Conclusions

We proposed a novel prediction tool for events sentiment assignment based on new semantic distance of ANPs and fusion of ANPs and nouns sentiments extracted from ego-centric photostreams. We introduced a new labelled dataset composed by 98 events. The proposed approach obtained a classification accuracy of 75% on the test set, with deviation of 8%.

References

1. Dimiccoli, M. et all: SR-Clustering: Semantic Regularized Clustering for Egocentric Photo Streams Segmentation. In: Computer Vision and Image Understanding (2015)
2. Chen, T. et all: DeepSentiBank: Visual Sentiment Concept Classification with Deep Convolutional Neural Networks. In: http://arxiv.org/abs/1410.8586 (2014)
3. Borth, D. et all: Large-scale visual sentiment ontology and detectors using adjective noun pairs. In: ACM International Conference on Multimedia (2013)

Interactive Three-Dimensional Visualization System of the Vascular Structure in OCT Retinal Images

Joaquim de Moura[1], Jorge Novo[1], Marcos Ortega[1], Noelia Barreira[1], and Manuel G. Penedo[1]

Departamento de Computación. Universidade da Coruña, A Coruña (Spain)
{joaquim.demoura, jnovo, mortega, nbarreira, mgpenedo}@udc.es

Abstract. This paper proposes an automated tool for the 3D visualization of the retinal arterio-venular tree using Optical Coherence Tomography (OCT) images. The system provides useful information to the doctors that can be of a great utility to obtain accurate diagnosis in a large variability of pathologies.

Keywords: computer-aided diagnosis, retinal imaging, OCT, vessel tree

1 Introduction

Computer-aided diagnosis (CAD) has become one of the major research subjects in medical imaging. OCT is a standard imaging technique in the ophthalmologic field because can provide non-invasive diagnostic images. This tomograph provides two types of images: a near infrared reflectance retinography and histological sections image of ocular tissues, as shown in Figure 1. Ophthalmologists use OCT retinal images for the analysis of the vascular tree and produce a diagnosis in different diseases. Therefore, the use of an automatic system for the 3D visualization of the vessel tree is relevant to facilitate the specialists work, increasing their productivity and helping to establish preventive and therapeutic strategies.

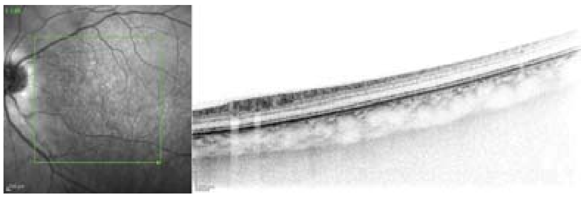
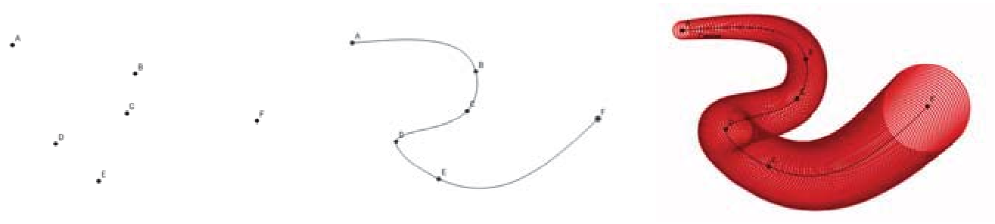


Fig. 1. Near infrared reflectance retinography and histological section example.

2 Methodology

The methodology takes advantage of different image analysis techniques to initially segment the vessel tree and estimate its calibers along it [1]. Then, the corresponding depth for the entire vessel tree is obtained [2]. Finally, with all this information, the 3D reconstruction of the vessel tree is achieved, interpolating with splines all the segments to obtain a smoother representation. Figures 2 (a), (b) and (c) illustrates this 3D representation process over a curve. This model allows the visualization and manipulation of the 3D vessel tree by means of graphical transformations including translation, scaling and rotation.

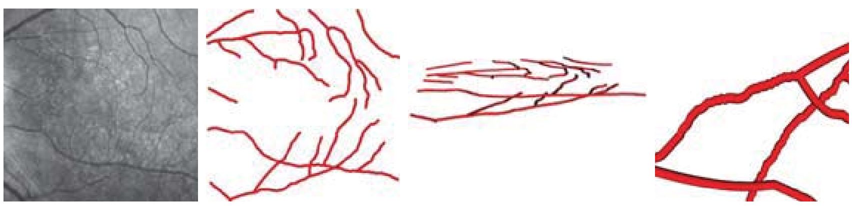


(a) (b) (c)

Fig. 2. Example of 3D representation process. (a) Set of points (x, y, z) of the plane. (b) Interpolation with splines between points. (c) 3D tube along a spline.

3 Results and Conclusions

This automated tool for 3D visualization of the retinal arterio-venular tree has been evaluated by an expert who has validated the functionality of the system. The methodology showed promising results, providing a coherent 3D vessel tree visualization that can be posteriorly used in different medical diagnostic processes of many diseases as, for example, hypertension or diabetes. Figure 3 illustrates with an example the result of the methodology.



(a) (b) (c) (d)

Fig. 3. Example of interactive 3D visualization of the vessel tree. (a) Input Near infrared reflectance retinography. (b) 3D Visualization of the vessel tree. (c) Rotation of the vessel tree. (d) Scaling of the vessel tree.

Acknowledgements

This work is supported by the Instituto de Salud Carlos III, Government of Spain and FEDER funds of the European Union through the PI14/02161 and the DTS15/00153 research projects and by the Ministerio de Economía y Competitividad, Government of Spain through the DPI2015-69948-R research project.

References

1. de Moura, J. and Novo, J. and Ortega, M. and Charlón, P.: 3D Retinal Vessel Tree Segmentation and Reconstruction with OCT Images. International Conference Image Analysis and Recognition 716–726 (2016).
2. de Moura, J. and Novo, J. and Ortega, M. and Barreira, N. and Penedo, M. G.: Vessel Tree Extraction and Depth Estimation with OCT Images. Conference of the Spanish Association for Artificial Intelligence 23–33 (2016).

A contour feature oriented system for Writer Recognition

Jose L. Vásquez[1], Juan Carlos Briceño[2], Carlos M. Travieso[3], Jesús B. Alonso[3]

[1]Sede del Atlántico, Universidad de Costa Rica, San José, Costa Rica
jose.vasquez@ucr.ac.cr
[2]Instituto de Investigación en Ingeniería, Universidad de Costa Rica, San José, Costa Rica
juan.briceno@ucr.ac.cr
[3]Institute for Technological Development and Innovation in Communications, Signals and Communications Department, IDETIC-ULPGC, University of Las Palmas de Gran Canaria. Las Palmas de Gran Canaria, SPAIN.
{carlos.travieso, jesus.alonso}@ulpgc.es

Keywords: Handwritten-based biometric, Writer Recognition, Writer Verification, HMM, SVM

Extended Abstract

Nowadays, automatic biometric systems try to identify a person by their intrinsic characteristics both physical and behavioral. Biometrics technology has several advantages over others identification methods and has been successfully proved in a wide variety of applications, where security is probably one of the most relevant.

Handwriting is a behavioral biometric characteristic which can be applied in different domains, such as security, financial activity, forensic, access control and others. Particularly, the off-line techniques are still valid and widely studied [1] [2]. For example, in legal matters, it is important to identify or verify individuals based on their writing. The act of writing is a complex phenomenon involving multiple personal factors. In the same way that a person can be identified by its peculiar form of laughing, gesturing, walking, etc., writing is determined by the personality of its author, and therefore, it has identifier capability [3].

Despite the different challenges facing the analysis of handwriting, automatic processing has had a great development in recent years [4] [5]. This work is part of the person recognition matter from its writing characteristics. In particular, we have designed and implemented a system for off-line writer identification and verification, which is based on word contour feature. The system uses a general angular form parameterization for initial input [6] and a classification system based on an HMM coding and a multidimensional classifier model. The results here exposed had been obtained from own database (DB) composed by 100 users with 10 samples per each one.

The DB used in this work was created at the University of Las Palmas de Gran Canaria, currently consisting of 100 different writers, with 10 samples per writer, each sample is a text in Spanish language. From each text were extracted the same 15 words, the DB contain one image per word for a total 15,000 images.

Each word were processed to correct skew and binarized by the method of Otsu, after that we apply an algorithm to define the contour word. Border determination as (x,y) positioning perimeter pixels of black intensity, has been achieved by processes of shadowing (white shape over black background), filtering of isolated points, and finally automatic perimeter points location x=column y=row coding, with a follow procedure point by point. Finally, we have a perimeter description of {(xi, yi) | i = 1,..,n} points location description; representing the closed border of a hand edge with one pixel of wide stroke.

Data compression, size regularization and critical control point selection of perimeters description are achieved by a structuring procedure. This procedure is based on the idea that a one pixel stroke on a black and white image may be described as a graph Gf of a one dimensional trajectory application f, if we have preservation of a correct sequencing definition or monotonic behavior on the x ordinate.

Cartesians descriptions are transformed in angular description using theirs central point as reference. Such description takes into account variation dependencies on sequential descriptions, and they are size and rotational independent (a useful attribute on images description). Such descriptions are coherent with Markovian chain descriptions.

Finally, taken into account the HMM component description we can define the HMM kernel (HMMK) as:

$$\frac{\delta}{\delta P(x,q)} \log P(x|q,\lambda) = \frac{\xi(x,q)}{b_q}(x) - \xi(q) \qquad \text{Where } \xi \text{ are HMM descriptors.} \quad (1)$$

In order to implement a classification system based on a Hidden Markov Model (HMM) from edge data, there is to follow three steps: the first one obtain an edge description, the second one is the transformation of data with a HMM coding, and finally the use of a Support Vector Machine (SVM) [7] as a classifier for each data collection.

This system gets a very good results, the Table 1 shows the success rate for identification of the 100 writers.. Using individual words we obtain a maximum success rate of 99.4% and a minimum of 98.6%. Additionally, the table 1 shows the results using some combinations of words. Importantly, any combination of four words achieved the success rate was 100%.

Table 1. Success rate for writer identification using words combinations. SVM (RBF), 50% of training percentage, g = 0.04.

Amount of words	Words	Success rate
1	bastante	99.4%
1	Española	98.6%
2	Cervantes, perfecta	99.6%
3	Cervantes, perfecta, Mancha	99.8%
4	Cervantes, perfecta, Ingenioso, Hidalgo	100%

For verification, the system also produces good results. The Table 2 shows the ERR index using different combinations of words.

Table 2. ERR for writer verification using words combinations. SVM (RBF), 50% of training percentage, g = 0.04.

Amount of words	Words	ERR
1	Cervantes	-0.19
1	universal	-0.76
2	Cervantes, perfecta	-0.53
3	Cervantes, perfecta, Mancha	-0.25
3	Española, positivista, necesidades, bastante	-0.46

References

1. Jain Anil, Golnaz Ghiasi, Reza Safabakhsh, Offline Text-Independent Writer Identification Using Codebook and Efficient Code Extraction Methods, Image and Vision Computing. doi: 10.1016/j.imavis.2013.03.002. (2013).
2. G. Louloudis, B.Gatos and N. Stamatopoulos. ICFHR2012 Competition on Writer Identification Challenge 1: Latin/Greek Documents. International Conference on Frontiers in Handwriting Recognition 2012.
3. Francisco de Antón y Barberá, Francisco Méndez Baquero; Análisis de textos manuscritos, firmas y alteraciones documentales. Ed. Tirant lo blanch. 2005.
4. Paraskevas, D.; Stefanos, G. ; Ergina, K.; " Writer Identification Using a Statistical and Model Based Approach", 14th International Conference on Frontiers in Handwriting Recognition (ICFHR-2014), pp. 589-594, 2014.
5. S.A.Angadi; Sharanabasavaraj.H.Angadi; "Structural features for recognition of hand written kannada Charater based on SVM", International Journal of Computer Science, Engineering and Information Technology (IJCSEIT), Vol. 5, No.2, pp. 25-32, 2015.
6. Briceño J.C., Travieso C.M.,Ferrer M.A., Alonso J.B.; Angular contour parameterization for signature identification. Computer Aided System Theory-EURACAST 2009.
7. Burges, C., 1998. A Tutorial on Support Vector Machines for Pattern Recognition. Data Mining and Knowledge Discovery. 2 (2), 121-167.

Deep Reinforcement Learning in Serious Games: Analysis and Design of Deep Neural Network Architectures

Aline Dobrovsky, Uwe M. Borghoff, and Marko Hofmann

Fakultät für Informatik
Universität der Bundeswehr München
85577 Neubiberg, Germany
{aline.dobrovsky,uwe.borghoff,marko.hofmann}@unibw.de

Extended Abstract

1 Deep Reinforcement Learning in Serious Games: Introduction and Motivation

Serious Games (SG) belong to the most important future e-learning trends; they attain enhanced public acceptance and importance [1]. Although more frequently used in recruitment and training, their production is still effortful and expensive. The generation of human behaviour and general game playing remain prevalent trends and challenges [2]. Serious games can profit from diverse behaviour to increase learning effectiveness and from general AI methods for easy adaption to different games. Deep reinforcement learning (DRL) offers an opportunity for application because it has shown considerable results and is widely applicable as a general method. DRL means the combination of reinforcement learning (cf. [3]) and deep learning methods (cf. [4]). A famous example is deep Q-learning for learning to play Atari games, where a convolutional neural network was trained with a variant of Q-learning on different Atari games and partially outperformed human game players [5].

We aim to expand and improve the application of DRL in SG through offering a novel framework, including partially automated adaption and interactive learning. An overview of the framework and its interactive learning component is described in [6]. In this paper, we will define the meaning of DRL architectures, examine promising examples and derive implications for concrete applications in SG. We will identify important factors, characteristics and dependencies for usage of DRL in SG through conceptual conclusions and experimental analyses on exemplary games. Our research is co-funded by the Federal Armed Forces of Germany within a project called Santrain. The goal of this project is the development of a serious game for first aid on the battlefield ("TCCC training"). DRL seems to be a promising way to generate adaptive behaviour for the opposing forces, which is considered to be vital for realistic learning.

2 Designing Architectures for Deep Reinforcement Learning in Serious Games

In this work, "architecture" denotes all characteristics that define the structure of the deep neural network component in DRL; including the general structure, types of layers (e.g. convolution, pooling) and connections, topology of different layers, weights and activation functions, etc. Although the problem is related to hyperparameter optimization, we mean to avoid the need for extensive optimization methods but rather assume that we can derive general recommendations for using DRL in SG. Our methodical approach comprises three stages:

Analysis of exemplary architectures Successful architectures (as described in [5]) are investigated. Several related domains and applications are considered, e.g. convolutional neural network architectures from image recognition and evolved architectures on computer games.

Conceptual design conclusions Considering the findings of our analysis, conceptual proposals for the network architecture are derived. We expect that structured requirements can be concluded and specified to define suitability of architectures for different application scenarios in SG.

Experimental investigation First experiments are conducted for examining selected architecture characteristics on exemplary games.

3 Conclusions and Future Work

We assume that, by utilizing specific DRL architectures, the usability of DRL in SG can be increased and that general criteria for such architectures can be derived. To the best of our knowledge, this paper will offer the first particular overview and analysis of DRL architectures with regard to applications in SG.

References

1. Doujak, G.: Serious Games und Digital Game Based Learning. Spielebasierte E-Learning Trends der Zukunft. GRIN Verlag München, Deutschland (2015)
2. Lara-Cabrera, R., Nogueira-Collazo, M., Cotta, C., Fernández- Leiva, A.J.: Game Artificial Intelligence: Challenges for the Scientific Community. In: Proceedings 2st Congreso de la Sociedad Española para las Ciencias del Videojuego Barcelona, Spain (2015)
3. Sutton, R.S., Barto, A.G.: Reinforcement learning: An introduction. MIT press (1998)
4. Deng, L., Yu, D.: Deep Learning: Methods and Applications. Technical report, NOW Publishers (2014)
5. Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A., Veness, J., Bellemare, M., Graves, A., Riedmiller, M., Fidjeland, A., Ostrovski, G. and others: Human-level control through deep reinforcement learning. Nature, vol. 518, no. 7540, pp.529–533 (2015)
6. Dobrovsky, A., Borghoff, U., Hofmann, M.: An Approach to Interactive Deep Reinforcement Learning for Serious Games. To appear in: Proceedings of 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom) 2016

Descriptors Comparisons for Vision based Speaker Diarization Approaches in Parliamentary Debates*

Pedro A. Marín-Reyes[1], Javier Lorenzo-Navarro[1], Modesto Castrillón-Santana[1], and Elena Sánchez-Nielsen[2]

[1] Instituto Universitario SIANI, 35017, Las Palmas, Spain, Universidad de las Palmas de Gran Canaria
[2] Departamento de Ingeniería Informática y de Sistemas, 38271, Santa Cruz de Tenerife, Spain, Universidad de la Laguna
pedro.marin102@alu.ulpgc.es

1 Extended abstract

Speaker Diarization deals with annotating who and when a speaker is talking, it represents a challenge for scientific community [1]. This problem can be tackled from a point of view of a re-identification process, detecting a speaker and checking whether he/she appears again.

Several approaches have been proposed to solve the diarization problem. They have been based on audio, video and a combination of both. Intensity Channel Contribution (ICC) [1], bottom-up hierarchical agglomerative clustering of Mel Frequency Cepstral Coefficients (MFCC) are used for audio. In video diarization, lips movement or face centered is used. Finally, as dual solution, audio and video descriptors are used, both descriptors have to keep the coherence.

In this paper, we are interested in diarization of parliamentary debates sessions based only on video. The scenario is composed of a presidential table, platform and seats, from deputies could intervene. Theses interventions are recorded by a network of cameras distributed in the Parliament, which can do pan, tilt and zoom.

To extract features, first the face is obtained as region of interest (ROI) and then local descriptors are extracted because they have demonstrated good performance in facial analysis [2]. After the speaker face is modeled, a matching stage is carried out by comparing the extracted features against the database models.

The experiments have been realized using 29 videos. Those videos variate in number of frames, shots and speakers. As features we have considered in the comparison the following ones: Histogram of Oriented Gradients (HOG), Local Binary Patterns (LBP), LBP Uniform (LBPu2), Intesity based LBP (NI-LBP), Local Gradient Patterns (LGP), Local Phase Quantization (LPQ), Local Salient Patterns (LSP0), Local Ternary Patterns (LTP), LTP high (LTPh),

* Work partially funded by TIN2015-64395-R.

LTP low (LTPl), Weber Local Descriptor (WLD) and Local Oriented Statistics Information Booster (LOSIB). They are calculated in the ROI using a 5×5 grid. At the time, the comparison of the models were calculated with Canberra, Chebyshev, Cosine, Euclidean and kullback–Leibler (KL) divergence histogram measures. Getting an idea of the number of experiments executed, 29 videos with 12 local descriptors with five different measures were processed, a total of 1740 experiments. Moreover, those experiments were validated by five diarization approximations, obtaining a total of 8700 experiments. Those diarization approximations are methods to evaluate the performance of the local descriptors under consideration, True Re-identification Rate (TRR) and True Distinction Rate (TDR) are used as measures [3]. Besides, for a specific speaker audio annotation, audio fragment, could appear different deputies shots in the video sequences. For this reason, we propose the following four approaches:

- First Appearance (FA): The person of the first shot detected by the system in the audio fragment is taken as representative speaker shot.
- Most Frequent (MF): The person that the system detect as greater number of occurrences in the audio fragment is taken as representative speaker shot.
- Greater Length (GL): The person that the system detect as higher duration shot in the audio fragment is taken as representative speaker shot.
- Greater Total Length (GTL): The person that the system detect as higher duration in the audio fragment is taken as representative speaker shot.

Considering the mean TRR and TDR, the best local descriptors are WLD (45.04%, 78,91%) and NILBP (44.97%, 77.15%), that behave better in this scenario. Then, if we focus on the descriptors comparison measures, the two higher are KL (49.47%, 70.98%) and Cosine distance (43.21%, 79.81%). Ultimately, comparing the employed approaches to evaluate the performance, MF and GTL achieve highest values.

To summarize this paper, four approaches to measure the performance of diarization problems have been proposed. Moreover, different local descriptors were compared, obtaining a general idea of their behavior. Finally, multiple histograms measures to matching have been compared, allowing us to know what configuration give us greater results for upcoming test.

References

1. R. Barra-Chicote, J. M. Pardo, J. Ferreiros, and J. M. Montero. Speaker diarization based on intensity channel contribution. *IEEE Transactions on Audio, Speech & Language Processing*, 19(4):754–761, 2011.
2. Castrillón-Santana, M., Lorenzo-Navarro, J., Ramón-Balmaseda, E.: Multi-scale score level fusion of local descriptors for gender classification in the wild. Multimedia Tools and Applications (in press) (2016), `http://dx.doi.org/10.1007/s11042-016-3653-2`
3. D.-N. T. Cong, L. Khoudour, C. Achard, C. Meurie, and O. Lezoray. People re-identification by spectral classification of silhouettes. *Signal Processing*, 90(8):2362 – 2374, 2010. Special Section on Processing and Analysis of High-Dimensional Masses of Image and Signal Data.

Detecting Hands in Egocentric Videos: Towards Action Recognition

Alejandro Cartas[1], Mariella Dimiccoli[1,2], and Petia Radeva[1,2]

[1] University of Barcelona,
Gran Via de les Corts Catalanes, 585, 08007 Barcelona, Spain
alejandro.cartas@ub.edu
[2] Computer Vision Centre,
Campus UAB, 08193 Cerdanyola del Valls, Barcelona, Spain

Over the last six years, there has been a growing interest in analyzing human daily activities from data collected by wearable cameras. Daily activities are crucial to characterize human behavior, and enabling their automatic recognition would pave the road to novel applications in the field of Preventive Medicine. The hands are involved in a wide variety of daily tasks, such as typing on a self-phone keyboard, drinking coffee or riding a bike. Along with the objects being manipulated in a scene, the hands are often the main focus in the egocentric field of view. Consequently, their detection is a fundamental step towards egocentric action recognition.

In this work, we propose a hand detector that exploits skin modeling for fast hand proposal generation and Convolutional Neural Networks for hand recognition. Our hand detector consists in a three-task architecture outlined in Fig. 1. We first detect regions containing skin pixels. Later, we generate a set of hand proposals using these regions. Finally, we classify the hand proposals using a Convolutional Neural Network (CNN).

Skin detection. For this task, we use the pixel-level skin detection (PERPIX) method [1]. We tested this method on the UNIGEN dataset [2], achieving true-positive and true-negative rates of 0.809 and 0.843, respectively. We showed that the PERPIX method offers competitive results using less than the 10 percent of the training data used in [2].

Hand proposal generation. We first determine if the estimated skin-region contains two arms. A two-arms region is segmented into two by first fitting the points from its medial-axis into two lines that should represent each arm. To make a soft segmentation, we obtain small regions using the watershed algorithm. Then, each small region is assigned to the closest line of the two (see Fig. 2c). Finally, we separate the hands from each one-arm regions by fitting a rectangular

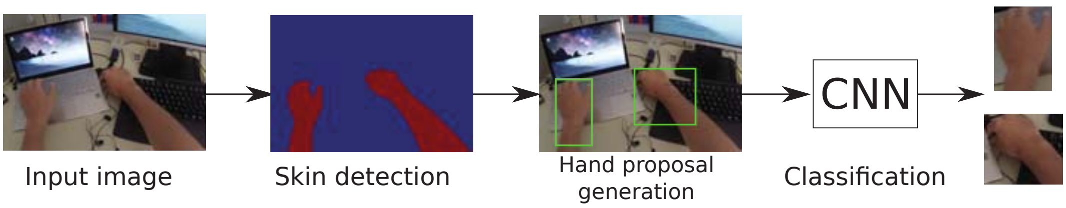
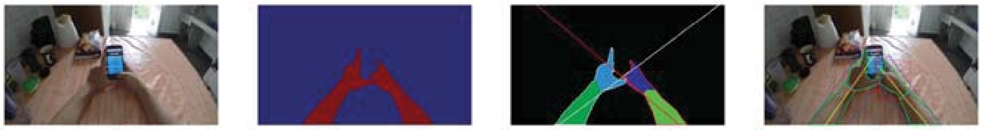


Fig. 1: Outline of the proposed method for hand detection.



(a) Original (b) Skin-detection binary mask (c) Arm segmentation (d) Hand contour cut

Fig. 2: Example of a hand proposal generation over a skin region containing two pixel-connected arms.

box from its contour. The side of the box closer to the center of the frame is considered to be the nearest to the hand. Consequently, we obtain the hand proposals by cutting the contour at different fixed distances from that side, see Fig. 2d.

Hand recognition. To classify a hand proposal we created a binary classifier by fine-tuning the CaffeNet network. Our training set was obtained by combining several datasets with bounding boxes of hands to obtain positive examples, and ImageNet to obtain negative examples. The total number of images and bounding boxes is 761,946 and 872,414, respectively.

Experimental results. We evaluated our method over a subset of 2,000 images from the UNIGE-HANDS dataset [2]. We manually annotated hands to allow a numerical evaluation. The number of images containing hands were 1,000 and in total they were over 1,739 hands. Fig. 3 shows precision-recall curves for four distinct values of intersection over union. We obtain an average precision (AP) of 0.216 when using the PASCAL VOC criteria.

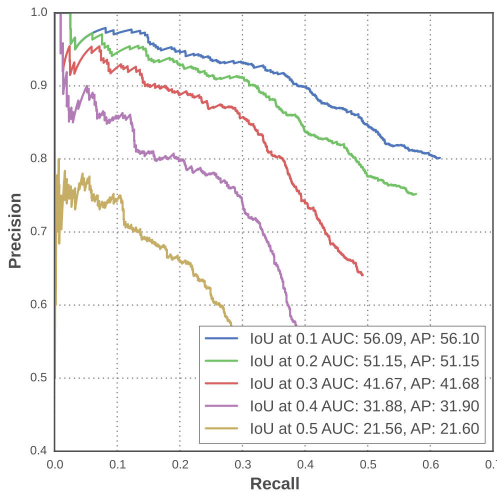


Fig. 3: Detection results on the UNIGEN test set for different values of the intersection over union (IoU) ratios.

Acknowledgments. This work was partially founded by TIN2015-66951-C2, SGR 1219, CERCA, *ICREA Academia'2014* and 20141510 (Marató TV3). A.C. was supported by the CONACyT grant 409755.

References

1. Li, C., Kitani, K.M.: Pixel-level hand detection in egocentric videos. In: Conference on Computer Vision and Pattern Recognition (CVPR), IEEE (2013) 3570–3577
2. Betancourt, A., Lopez, M., Regazzoni, C.S., Rauterberg, M.: A Sequential Classifier for Hand Detection in the Framework of Egocentric Vision. In: Conference on Computer Vision and Pattern Recognition. Volume 1., Columbus, Ohio, IEEE Computer Society (2014)

Exploring Food Detection using CNNs

Eduardo Aguilar, Marc Bolaños, and Petia Radeva

Universitat de Barcelona and Computer Vision Center, Spain
eaaguilart@gmail.com,{marc.bolanos,petia.ivanova}@ub.edu,

Abstract. Building an automatic system for dietary assessment would allow a better estimate of caloric intake than traditional methods. The computer vision community has focused its efforts in areas as food detection, food recognition, portion estimation and calorie intake. For food detection, the best results have been obtained using Convolutional Neural Networks (CNN). However, these results are obtained on different datasets and are not directly comparable. This article proposes an overview of the last advances on food detection and an optimal model based on CNN methods and an SVM that outperforms the state of the art.

1 Introduction

In the last decades, the amount of people with overweight and obesity is progressively increasing. Recently, the computer vision community has focused its efforts on developing automated systems for dietary assessment, which usually involve a food detection system. In [5], the authors apply fine-tuning on the last two layers of a GoogLeNet obtaining high accuracy, but test their model on only 5000 images. In [1], the authors propose an AlexNet model for food detection, achieving a 4% higher accuracy with respect to the baseline, getting a 93.8% on a dataset of 3,214 images acquired from social media. In [2], the authors improve the accuracy on this dataset to 99.1% using a NIN model. In addition, they evaluate their model on other datasets, IFD and FCD, obtaining 95% and 96% of accuracy. An evaluation of different CNN models and settings was proposed by [3] on a dataset, we call RagusaDS. The authors get the best results using AlexNet (fine-tuned) and Binary SVM. In terms of accuracy, they achieved 94.86%. In this article, we propose a food detection model that provides the best accuracy in the state of the art with respect to different available food datasets.

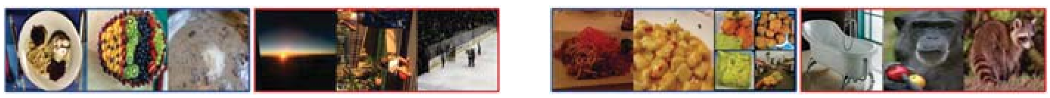


Fig. 1. Food (blue) and non-food (red) images from RagusaDS (left) and FCD (right) datasets.

2 The food detection approach

We propose a methodology for food detection, which involves the use of the GoogLeNet model for feature extraction and SVM for classification. In our experiments, we pre-train the network on ImageNet images. Then, the GoogLeNet is fine-tuned during 10 epochs, in the case of FCD dataset, and during 40 epochs for RagusaDS, using the training set of the respective datasets. We evaluate the accuracy on food detection on the validation set, and select the model that gets the best accuracy. From this model, the image features are extracted for each image contained in the training and validation sets. Then, we use it as a feature vector to train a SVM classifier using the GridSearchCV.

Table 1. State of the art food detection methods

	Algorithm	**Dataset**	**#Images**	**Accuracy**
[3]	AlexNet + SVM	RagusaDS	16,393	94.86%
Our	GoogLeNet + SVM	RagusaDS	16,393	**95.62%**
[2]	CNN-NIN	FCD	53,572	96%
Our	GoogLeNet + SVM	FCD	53,572	**98.22%**
Our	GoogLeNet + SVM	FCD + RagusaDS	69,965	**97.14%**

3 Results and Conclusions

We evaluated the food detection using traditional GoogleNet with fine-tuning, and also GoogleNet with SVM. We used the following public datasets for food detection, since they contain a significant amount of images (more than 15,000): a) RagusaDS from [3], that contains 16,393 images in total, selected from Flickr of food and non-food and from UNICT-FD889 of food images, and b) FCD that consists of 53,572 images in total, composed by food images from Food101 dataset [4] and by non-food images from Caltech256. The results show that better accuracy is achieved in both datasets when GoogleNet is used for feature extraction and then SVM for classification. As showed in Table 1, we obtained the best accuracy with respect to the state of art on the datasets evaluated with improvements of 2% and 1% over the models of [2] and [3], respectively. Combining both datasets, our model obtained 97,14% of accuracy. As a conclusion, we explored the problem of food detection comparing the last works in the literature and proposed a model based on GoogLeNet and SVM, which provides an improvement over the state of the art with respect to two public datasets. Moreover, models based on GoogLeNet, independently of the settings, gave the highest accuracy on the food detection problem.

References

1. Kagaya, H. , Aizawa, K. , Ogawa, M.: Food Detection and Recognition Using Convolutional Neural Network. In: Proc. 22nd ACM Multimedia. 1085–1088, 2014.
2. Kagaya, H., Aizawa, K.: Highly Accurate Food/Non-Food Image Classification Based on a Deep Convolutional Neural Network. In: LCNS pp. 350–357, 2015.
3. Ragusa, F., Tomaselli, V., et.al. : Food vs Non-Food Classification. In: Proc. 2nd Int. Workshop Multimedia Assisted Dietary Management. 77–81, 2016.
4. Bossard L, Guillaumin M, Van Gool L. Food-101mining discriminative components with random forests. ECCV 2014.
5. Singla, A., Yuan, L., et.al.,: Food/Non-food Image Classification and Food Categorization using Pre-Trained GoogLeNet Model, MADiMa, ACM Multimedia, 2016.

An Advanced Hardware Platform for Modern Hand-Prostheses

Peter Hegen and Klaus Buchenrieder

Universität der Bundeswehr München
Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany
{peter.hegen,klaus.buchenrieder}@unibw.de

Extended Abstract

The field of hand prostheses has seen a number of advances in recent years. Commercial off-the-shelf prostheses have gotten ever more sophisticated, introducing new designs that allow the individual movement of fingers. Similarly, research prostheses got a lot of new functionality and articulation [1]. Unfortunately, research prostheses are often custom-made (e.g. [2]) by the respective team, requiring a huge amount of effort and development steps done over and over again. Part of the problem is that commercially available prostheses are not designed to be modified or re-used for research. Additionally, these still rely on an analog-only interface introduced decades ago. As such, the underlying control scheme is very limited and can not be altered, making hand prostheses unsuitable to test new algorithms and control schemes during research.

The system brought forward in this contribution alleviates this problem by introducing an open replacement for the electronics of the commercial bebionic hand prosthesis from Steeper Inc. (Leeds, UK). Having both a digital as well as an analog interface it is backward compatible and allows for a larger number of digital sensors to be connected to it.

Figure 1 shows the main data/control flow of the prosthesis. Two or more electromyographic (EMG) sensors sample the myoelectric signal present on the surface of the patients skin. In case of an analog sensor, the amplified and pre-conditioned signal is sampled using an on-board analog-to-digital converter (ADC) subsequently processed by the main microcontroller unit (MCU).

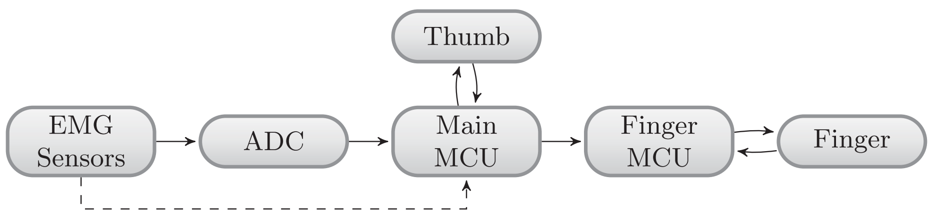


Fig. 1. Conceptual architecture of the data and control flow of the prosthesis. The ADC stage is optional when EMG sensors with a digital interface are used.

For sensors with a digital interface (containing the ADC inside the sensor), the ADC stage is skipped. Based on the incoming signal, the motor for each finger is actuated. While the control from the index to the pinkie is offloaded to separate motor controller boards situated in each finger, the thumb is controlled directly by the main MCU. This design was kept from the original electronics. Figure 2 depicts the new electronics with the main controller board on the right and the motor from the index finger on the left.

The firmware for the system is based on FreeRTOS$^{\mathrm{TM}}$ and implements both the classical control scheme as well as one based on multiple features and an LDA classifier. Digital filters provide for an alternative to the fixed filters implemented in hardware. This flexibility allows to easily adapt the prosthesis to different situations, e.g., elimination of ripple voltage (50 Hz, 60 Hz or even 400 Hz in avionic systems). When the prosthesis is in use, a logging subsystem records the raw signals onto an SD-card, facilitating research with actual patient data instead of those recorded from healthy subjects in a lab setting.

Current research targets to combine the digital and analog interface to improve interoperability with different systems. Further, we anticipate to include additional sensors such as inertial measurement units as integral parts of the prostheses to detect/offset motion artifacts.

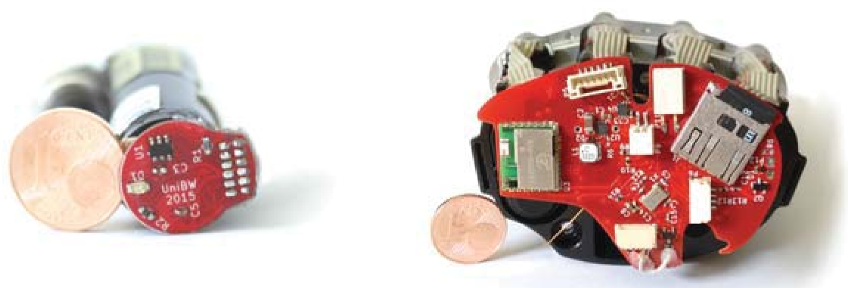


Fig. 2. Image of our custom electronics of the motor controller for a single digit (left) and of the mainboard (right), each with a one cent coin (Euro) for size comparison.

References

1. Resnik, L., Klinger, S.L., Etter, K.: The DEKA Arm: Its features, functionality, and evolution during the Veterans Affairs Study to optimize the DEKA Arm. Prosthetics and Orthotics International, vol. 38, no. 6, pp. 492–504, 2014
2. Krausz, N.E., Rorrer, R.A.L., Weir, R.F.ff.: Design and Fabrication of a Six Degree-of-Freedom Open Source Hand. In: IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 24, no. 5, pp. 562-572, 2016

A Real-Time Classification System for Upper Limb Prosthesis Control in MATLAB

Andreas Attenberger[1] and Sławomir Wojciechowski[2]

[1] FH Kufstein
University of Applied Sciences
Kufstein, Austria
andreas.attenberger@fh-kufstein.ac.at
[2] Wrocław University of Science and Technology
Wrocław, Poland
swojciechowski@pjwstk.edu.pl

Extended Abstract

Despite the significant amount of academic research on pattern recognition for hand prostheses, clinical application is still insufficient. The underlying control strategies of even modern myoelectric hand prostheses date back to the 1950s [1]. As a consequence, longterm acceptance by patients is significantly reduced [2]. Among the reasons are restricted functionality of these devices as well as a lack of clinical trials for classification-based control [3], with the bulk of of existing research relying on pre-recorded myoelectric signals [2]. A possible solution for these problems is a system for testing classification-based control systems in real-time. Furthermore, the introduction of novel sensing technology like near-infrared (NIR) spectroscopy can further improve classification results [4].

In this paper we present a MATLAB tool for processing both EMG and NIR sensor signals in real-time in order to provide a fully operational tool for clinical testing. All steps of the multi-stage classification process as proposed by Englehart et al. [5], including feature extraction, classifier training as well as the operational classifier phase for actuating the prosthesis, are provided. The hardware setup consists of custom-built sensors with combined EMG and NIR sensing capability connected to a PC equipped with a NI DAQ system as shown in Figure 1. After a short training phase, the decision tree classifier produces output for actuating a Michelangelo hand by Ottobock Healthcare. To validate the system design, it was tested with four probands performing wrist flexion, wrist extension and fist hand movement patterns. After a training phase, features were extracted in real-time from either the EMG or NIR sensor data for classification with the model created during the training phase. In this setup, NIR sensor data alone proved to be sufficient for distinguishing three hand movement patterns with two sensors. The classification accuracy is equal or better to standard EMG data recorded from the same sensor pick-up area on the forearm. However, setting an appropriate signal strength threshold is equally challenging for NIR sensor signals.

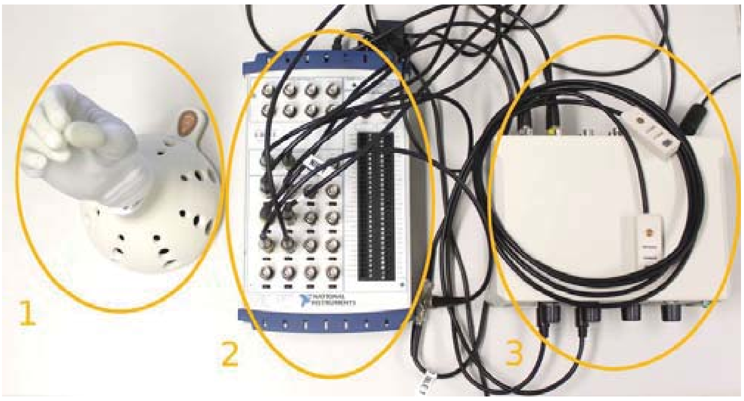


Fig. 1. The hardware setup for acquiring NIR and EMG signals with the (1) Michelangelo hand for prosthesis actuation (2) the data acquisition system and (3) the combined NIR-EMG sensors and amplifier.

Future work will be focused on the simultaneous real-time classification of both NIR and EMG sensor data to improve the reliability of these pattern-recognition-based control schemes. Furthermore, the approach should be extended with a higher number of tested grip patterns and different feature extraction methods for the two sensing methods.

Acknowledgment

The authors are grateful to Prof. Klaus Buchenrieder of the Universität der Bundeswehr for his support of their research as well as Otto Bock Healthcare for supplying the Michelangelo hand employed for testing the control scheme.

References

1. Jiang, N., Dosen, S., Müller, K.R., Farina, D.: Myoelectric control of artificial limbs - Is there a need to change focus. IEEE Signal Process. Mag **29**(5) (2012) 152–150
2. Peerdeman, B., Boere, D., Witteveen, H.J.B., Huis in 't Veld, M.H.A., Hermens, H.J., Stramigioli, S., Rietman, J.S., Veltink, P.H., Misra, S.: Myoelectric forearm prostheses: State of the art from a user-centered perspective. Journal of rehabilitation research and development **48**(6) (August 2011) 719–738
3. Scheme, E., Englehart, K.: Electromyogram pattern recognition for control of powered upper-limb prostheses: State of the art and challenges for clinical use. Journal of rehabilitation research and development **48**(6) (2011) 643
4. Attenberger, A., Buchenrieder, K.: Modeling and visualization of classification-based control schemes for upper limb prostheses. In Popovic, M., Schätz, B., Voss, S., eds.: IEEE 19th International Conference and Workshops on Engineering of Computer-Based Systems, ECBS 2012, Novi Sad, Serbia, April 11-13, 2012, IEEE Computer Society (2012) 188–194
5. Englehart, K., Hudgins, B., Parker, P., Stevenson, M.: Classification of the myoelectric signal using time-frequency based representations. Medical Engineering & Physics **21**(6-7) (1999) 431–438

Mild Cognitive Impairment Detection using an Intelligent Computing Solution and by Clinicians: A Performance Comparison

Carmen Paz. Suárez-Araujo[1], Norberto Rodríguez Espinosa[2] Carlos Fernández Viadero[3]and Patricio García Báez[4]

[1] Instituto Universitario de Ciencias y Tecnologías Cibernéticas, Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Canary Islands, Spain
[2] Unidad de Neurología, Conducta y Memoria. Hospital Nuestra Señora de la Candelaria, Santa Cruz de Tenerife, Canary Islands, Spain
[3] Unidad de Atención a la Dependencia de Santander, Santander, Spain
[4] Departamento de Ingeniería Informática y de Sistemas, Universidad de La Laguna, La Laguna, Canary Islands, Spain,
{carmenpaz.suarez@.ulpgc.es, nrodesp@ull.es, cfdezviadero@ono.com; pgarcia@ull.es}

Keywords: Mild Cognitive Impairment, Counterpropagation Networks, Diagnosis, Primary Care Physicians, Neurologist, Geriatrician

Extended Abstract

The Mild Cognitive Impairment (MCI) concept was proposed to group patients that only display an intermediate cognitive deficit between the normal aging and the dementia stage, without significant functional impact [1]. These patients present an increased risk of conversion to dementia, with annual rates between 5 and 10%. Because of this, early detection of MCI is important. It is also considered to be beneficial because it allows treatment in the initial stages to begin, which can extend the autonomy of the patients. Diagnostic procedure for MCI is usually started by general practitioners. However the level of detection at this setting is consistently low and diagnosis may be delayed for months to years. It is a complex and uncertain diagnosis. Intelligent computing methods can be useful to aid in clinical decision making [2]. In this paper, using a hybrid neural architecture we provide a diagnostic tool that facilitates a reliable MCI estimate. It is based in brief and common clinical and functional batteries, easily obtained in primary care, and some risk factors, as age and educational level. Our main aim was to explore the ability of this intelligent system to differentiate healthy controls and MCI patients and to compare the computational solution and clinical physician diagnostic performances.
The intelligent system for MCI detection was achieved by joining a hybrid modular neural architecture, Counterpropagation network (CPN), with a wrapper approach for feature selection, using a backward elimination search strategy.

All participant data were obtained from the ADNI database (www.loni.ucla.edu/ADNI). As inputs were selected MMSE, Functional Assessment Questionnaire (FAQ), Geriatric Depression Scale (GDS), years of education and patient's age [3]. Four experienced clinicians, a geriatrician, a neurologist and two family physicians, blinded to other diagnostic instrument measures, were asked to classify the subjects as MCI or normal controls based on the same clinical measures that CPN-based system did.
The accuracy (Acc), sensitivity (Se), specificity (Sp) and AUC values were determined to compare and rank the different developed CPN-based systems. They were also used to compare the performance of the best proposed intelligent computing solution, with the doctor's diagnosis. The Clinical Utility Index was also calculated.
The optimal CPN configuration was obtained with the MMSE, FAQ and age input combination, reaching a 95,11% of AUC. The CPN based system was superior to clinician´s performance. Its Se was 90,00%, and Acc =86,84%, while overall clinicians Se and Accs were lower, 86,67% and 77,63% for neurologist, 56,67% and 78,95% of geriatrician and 23,33% and 69,74%, 20% and 68,42%, of the primary care physicians. The only performance measurement that was better than CPN-based system is the Sp of the geriatrician and the two primary care physicians. These values reveal a large disparity in the trade-off between sensitivity and specificity for the clinician diagnosis. All the physicians CUIs were also worse than the CPN system.
From these results we can conclude the proposed CPN based system, may be a reliable tool for MCI diagnosis in primary care setting.
We can observe that clinician's diagnosis accuracy it's in the low-medium range and varies from one clinician to other. The different results between clinicians could be by their different approach to patients and their diseases. Probably the cognitive components are the main aspect for the neurologist, functional components for geriatrician and a holistic point of view by the primary care physicians. Our proposal allows homogenizing the diagnostic probability regardless of physician's capacity.
Finally, this study reveals interesting discoveries on diagnosis process in daily clinical, which can be modified following the achieved results. Our proposal can improve the early diagnostic performance of MCI in primary care setting and it also can address for eliminating the possible patients bottle neck among different clinical settings. The latter it is a very important aspect, because this solution prevent that any subject with MCI doesn´t access to specialized setting.

References

1. Petersen RC, Smith GE, Waring SC, et al. Mild cognitive impairment: clinical characterization and outcome. Arch Neurol. 1999 Mar; 56(3):303-8
2. García Báez, P., Suárez Araujo, C.P. and Martinez García, J.M.; Artificial Neural Networks in Alzheimer's Diagnosis. A perspective; Alzheimer's Disease Research Journal, Volume 4, Issue 4, pp: 413-442; 2011
3. P. G. Báez, C. F. Viadero, N. R. Espinosa, M. A. Pérez del Pino and C. P. Suárez-Araujo, "Detection of mild cognitive impairment using a counterpropagation network based system. An e-health solution," *(IWCIM), 2015 International Workshop on*, Prague, 2015, pp. 1-5. doi: 10.1109/IWCIM.2015.7347094

The Metamodel of Heritage Preservation for Medical Big Data

Zenon Chaczko[1], Lucia Carrion Gordon[1], Wojciech Bozejko[2]
[1] University of Technology, Sydney Australia, Sydney
[2]Institute of Computer Engineering, Control and Robotics, University of Technology, Wroclaw, Poland
Zenon.Chaczko@uts.edu.au[1], Lucia.CarrionGordon@uts.edu.au[1], Wojciech.Bozejko@pwr.wroc.pl[2]

Abstract. At present the real challenge of Digital Data Preservation concerns methods of keeping all important attributes of the data and preserving their originality. The key is to keep the living part of the data. It is the essence of the Heritage concept. The Heritage is about the concrete data, the concept gives the interconnection to other aspects of the reality. Nowadays the physical value and the aspects of items complete the relevance of information. The question of what is the heritage and what parameters define the artifacts' heritage? The context and the interpretation of data is the answer. The heritage term is defining as the crucial and central part of the presented research, and we can refer the heritage term as: '…those items and places that are valued by the community and is conserved and preserved for future use or reference by the future generations'.

Keywords: Metamodel, Preservation, Digital, Heritage, DHP, Ontology, Management,

1. Introduction

There are two tendencies around the understanding of the management of the ideas. The ontology and the Epistemology of this study, centralized the future use and the Serendipity tendency of the item. However, in the perspective of the nonphysical items there is a World of Physical and Logical and how the Preservation need to look items and how will be the manifestation. Digital Preservation has evolved into a specialized, interdisciplinary research. Through the time the challenge in to jointly develop solutions. As the patterns and alternative solutions there are Information Retrieval and, Machine Learning or Software Engineering. The Digital Preservation [1] show us the reality of the understanding of the World about the facility to have digital expressions rather than just physical. The Heritage of the collected information define the quality of the Data. This is specifically important in medical field. At this stage, the definition of Heritage involved the presence not only the content. It is the express by itself the real meaning of the data. The perception of the importance and relevance of the information is measured through the definitions and the proposed metamodel. Digital Data and Heritage Preservation concepts are related to medical data management, contextualization and storage. There are many related issues. This research explores the definition, context and the need of patterns of heritage specifically in medicine. The relations, interpretation and context give us the appropriate methods to keep information for a long term use. The management of massive amounts of medical data involves designing, modeling and processing.

2. Patterns, the Metamodel and the Ontology of DHP

The Metadata Model explores dynamic data representations and specifically the new relations, their origin and the mechanism(s) that generate these relations. The formatting of information provides the unique result as a digital age of the information.

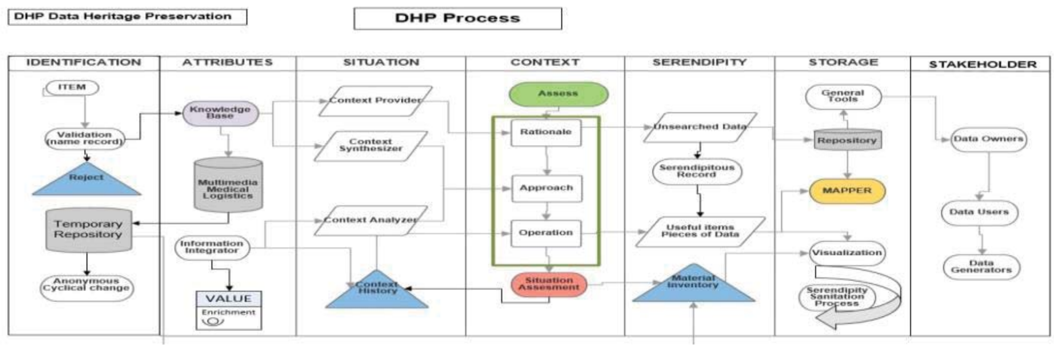


Figure 1. DHP Process

Other objective is the knowledge management and ontology [2, 3] as techniques for analyzing information. One concern of digitalization would be the formatting, standards and migration of the data. It should be solved with the use of Architectural Methodology and with the development of a fast prototype. This requires the definition of the sequential process. First, we consider a Framework front-end and for reception of the information in a basic way. Using the Open Group Architectural Framework is found to be suitable for the dissemination of the data, as it is associated with an Ontology and Knowledge Management terms and to be more specific with a deeper sense of the definition. Secondly, the Methodology with an architectural vision using concepts of Architectural Development Method. It has been identified in terms of enterprise description for validating information of several types of data. Thirdly, the conceptualization of patterns for a centralization of the preservation knowledge providing a unique result: the digital age of the data. The connection is also with the artefacts and the correct use of them. The recovering of the information is another issue should consider between the techniques used for this purpose like: migration and emulation. The challenges and constraints shown by the type of data classified as structured and unstructured information are reflected in the requirements of each field. The evaluation is based on PRIST model defining by Privacy, Rights, Integrity, Security and Trust (TOGAF +ADM+PRIST) across PC considerations related with Physical and Cognitive characteristic of data [4]. The authenticity of the information and the reliability of the same is the principal challenge of the study. The concepts of e-infrastructure are useful for the evaluation of requirements in specific cultural matters like Libraries. The proposed metamodel aims to provide an alternative for the understanding of the Heritage Preservation concept that relates to important dimensions around the processed data and its origins. The different dimensions of the Digital Heritage Preservation capture the real significance of Data Heritage.

3. References

[1] S., Becker, C., Neumayer, R. & Rauber, A. 2007, 'How to choose a digital preservation strategy: evaluating a preservation planning procedure', Proceedings of the 7th ACM/IEEE-CS joint conference on Digital libraries, Vancouver, BC, Canada.

[2] Syerina Azlin Md, N. & Noor, N.L.M. 2010, 'Integrating ontology-based approach in Knowledge Management System (KMS): construction of Batik Heritage Ontology', Science and Social Research (CSSR), 2010 l Conference, pp. 674-9.

[3] Thalmann, S., Seeber, I., Maier, R., Ren, #233, Peinl, Pawlowski, J.M., Hetmank, L., Kruse, P. & Bick, M. 2012, 'Ontology-based standardization on knowledge exchange in social knowledge management environments'. Proceedings of the 12th International Conference on Knowledge Management and Knowledge Technologies, Graz, Austria. pp. 1–8, 2012.

[4] Gordon, L. & Chaczko, Z. 2015, 'Digital Patterns for Heritage and Data Preservation Standards', in G. Borowik, Z. Chaczko, W. Jacak & T. Łuba (eds), Computational Intelligence and Efficiency in Engineering Systems, vol. 595, Springer International Publishing, pp. 47-59.

An Assessment of Laparoscopic Training Systems

Ryszard Klempous[1], Konrad Kluwak[1], Jan Nikodem[1], and Dariusz Patkowski[2]

[1] Faculty of Electronics, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
[2] Department of Pediatric Surgery and Urology, Medical University of Wroclaw, M. Curie-Skłodowskiej 52, 50-369 Wroclaw, Poland
{ryszard.klempous, konrad.kluwak, jan.nikodem}@pwr.edu.pl, mail@patkowski.eu

Keywords: virtual reality, laparoscopic surgery training, endoscopic techniques, simulation laparoscopic training assessment

Extended Abstract

One of the areas of research during the period of last ten years in the ViMed laboratory at Wroclaw University of Science and Technology is application of virtual reality method for laparoscopic surgery training [2–5]. The number of surgical advanced procedures using endoscopic techniques is growing steadily. The endoscopic surgery requires special skills which are difficult to acquire in operating room [10, 11]. The simulation teaching performed on laboratory models offers opportunity to provide hands on experience. Discusses the effects of reconstruction algorithms for 3D scene based on images from the camera for operational training [7]. A key element of the system is a new approach to training [9], in which a 3D model of the operative field is the basis of the interaction between the trainees (vets and surgeons) a simulation system. Presents and discusses the outline of the 3D processing algorithm and the results of a test for a group of 16 vets and 20 surgeons. The tests were conducted on simulators LapSim (http://www.surgical-science.com/lapsim-the-proven-training-system/) and eoSim SurgTrac (http://www.eosurgical.com/). The number of parameters assessed were equal 22 and 21 respectively.

1. LapSim - 22 parameters : Start Time, Score, Status, Total Time (s), Left and Right Instrument: Misses (%), Path Length (m), Angular Path (degrees), Outside View (#, s); Tissue Damage (#), Maximum Damage (mm), Grasper Collided with Left Box (#), Left Box Lifted (#), Left Box Min Exposure Angle (degrees), Grasper Collided with Right Box (#), Right Box Lifted (#), Right Box Min Expo-sure Angle (degrees)
2. eoSurgical – 21 parameters : time, left and right hand appliance of: distance between(cm), acceleration(mm/s2), distance(m), handedness(%), off screen(%), smoothness(mm/s3), speed(mm/s)

To evaluate the quality of the training very fruitful was our experience in the areas for performance assessment in computerized surgical training system[8] as well as an assessment of education process management [1, 6] .Also methods developed in other centers [12, 13]. Two laparoscopic simulators systems for training surgeons and vets were tested using virtual reality. The effects make a very important contribution to the development of many fields such as: modeling, identification and medical diagnostics.

References

1. Chaczko, Z., Klempous, R., Nikodem, J., Rozenblit, J.: Assessment of education process management. In: SAMI, IEEE (2016) 263-267
2. Nikodem, J., Wytyczak-Partyka, A., Klempous, R. In: Application of Image Processing and Virtual Reality Technologies in Simulation of Laparoscopic Procedures. Springer (2015) 463-470
3. Klempous, R., Nikodem, J., Wytyczak-Partyka, A. In: Application of simulation techniques in a virtual laparoscopic laboratory. Springer (2012) 242-247
4. Wytyczak-Partyka, A., Nikodem, J., Klempous, R., Rozenblit, J., Klempous, R., Rudas, I. In: Safety Orient. Lap. Surgery Training System. Springer (2009) 889-896
5. Wytyczak-Partyka, A., Nikodem, J., Klempous, R., Rozenblit, J.: A novel interaction method for laparoscopic surgery training, IEEE (2008) 858-861
6. Chaczko, Z., Dobler, H., Jacak, W., Klempous, R., Maciejewski, H., Nikodem, J., Nikodem, M., Rozenblit, J., Araujo, C.P.S., Sliwinski, P.: Assessment of the quality of teaching and learning based on data driven evaluation methods. In: ITHET, IEEE (2006) nil21-nil36
7. Napalkova, L., Rozenblit, J.W., Hwang, G., Hamilton, A.J., Suantak, L.: An optimal motion planning method for computer-assisted surgical training. Applied Soft Computing 24 (2014) 889-899
8. Riojas, M., Feng, C., Hamilton, A., Rozenblit, J.: Knowledge elicitation for performance assessment in a computerized surgical training system. Applied Soft Computing 11(4) (2011) 3697-3708
9. Rozenblit, J.W., Feng, C., Riojas, M., Napalkova, L., Hamilton, A.J., Hong, M., Berthet-Rayne, P., Czapiewski, P., Hwang, G., Nikodem, J., et al.: The computer assisted surgical trainer: design, models, and implementation. In: Summer Simulation Multiconference, Society for Computer Simulation International (2014) 211-220
10. Patkowski, D., Chrzan, R., Wrobel, G., Sokol, A., Dobaczewski, G., Apoznanski, W., Zaleska-Dorobisz, U., Czernik, J.: Laparoscopic splenectomy in children: experience in a sin-gle institution. Journal of Laparoendoscopic & Advanced Surgical Techniques 17(2) (2007) 230-234
11. Esposito, C., Escolino, M., Miyano, G., Caione, P., Chiarenza, F., Riccipetitoni, G., Yama-taka, A., Savanelli, A., Settimi, A., Varlet, F., et al.: A comparison between laparoscopic and retroperitoneoscopic approach for partial nephrectomy in children with duplex kidney: a multi-centric survey. World journal of urology (2015) 1-10
12. Jimbo, T., Ieiri, S., Obata, S., Uemura, M., Souzaki, R., Matsuoka, N., Katayama, T., Masu-moto, K., Hashizume, M., Taguchi, T.: Effectiveness of short-term endoscopic surgical skill training for young pediatric surgeons: a validation study using the laparoscopic fundoplication simulator. Pediatric surgery international 31(10) (2015) 963-969
13. Nasr, A., Gerstle, J.T., Carrillo, B., Azzie, G.: The pediatric laparoscopic surgery (pls) simulator: Methodology and results of further validation. Journal of pediatric surgery 48(10) (2013) 2075-2077

Learning-based Object Tracking for Transfer Tasks in Laparoscopy Training

Kuo Shiuan Peng, Minsik Hong, Jerzy Rozenblit

Electrical and Computer Engineering, The University of Arizona, Tucson, The United State
{kspeng, mshong, jerzyr}@email.arizona.edu

Abstract. A real-time, image-based training scenario comprehension method is proposed in this paper. This method is being developed to support a visual and haptic guidance system for laparoscopic surgery skills training. The target task of the proposed method is a simulation model of a peg transfer task, which is one of the hands-on exam topics in the Fundamentals of Laparoscopic Surgery certification. A machine learning-based image understanding is proposed to generate a system object state of the peg transfer task to support the guidance system. An Artificial Neural Network (ANN) is used to discern the object state by using without the aid of any object template or model.

Keywords: Medical simulation; simulation-based surgical training; laparoscopy; image understanding; machine learning.

1 Introduction

Laparoscopic surgery is a popular technique, which benefits patients by minimal invasiveness and fast recovery time. However, to be a well-trained surgeon, one needs extensive practice in a simulated environment before operating on patients. A simulation-based training device, Computer Assisted Surgical Trainer (CAST) [1] [2], has been designed for laparoscopic surgery skills training. CAST is a simulation-based training device with visual and haptic guidance rendered to its users.

The Fundamentals of Laparoscopic Surgery (FLS) [3] program was developed by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). This program has multiple hands-on exams for trainees to learn the basic laparoscopic skills. The first hands-on exam in FLS program is the peg transfer task. In a simplified scheme, trainees need to manipulate one instrument to grasp a rubber ring like object (triangle) from a peg, carry this triangle in mid-air, and then place the triangle on a different peg on the other side of the board. In this task, CAST provides trainees visual and haptic guidance based on the system object's states [4]: *hold*, *move*, *grasp*, *carry*, *put*, and *drop*.

In the peg transfer task, the intuitive way to detect the state is to use images from a camera. This process is often called object tracking [5]. In this paper, we propose a learning-based object tracking (LBOT) method without using any object template [6] or model to detect the object state of the transfer task.

2 Design concept and architecture

The design concept of LBOT is driven by the need to simulate the system object for our problem. The detected state is the basis of the visual and haptic guidance of the CAST system. LBOT provides real-time implementation of the state detection.
The system is composed of two major processes: a) feature extraction and b) classification. The system inputs are two consecutive frames of the source video image sequence, and the system output is the object state. In the process of feature extraction, the input images are processed by considering several features such as luminance, color, and motion difference. These features are utilized to synthesize the feature image. The second process is classification, which converts the feature images to system object state by using an Artificial Neural Network (ANN) algorithm [7]. The predefined feature image and object state training sets are fed to the ANN whose kernel is generated in an offline manner. Using this ANN kernel, the system object state can be calculated from the input feature image in the online, real time mode.

3 Summary

This paper proposes an LBOT method to detect the system object state of the peg transfer task in the FLS program. This method detects the state based on the image feature extraction and an ANN algorithm without any object templates or models. We will demonstrate its robustness and efficiency to meet requirements of real-time applications (training tasks) in the CAST system. Although the LBOT method is currently implemented in the simplified peg transfer, it has a great potential to be extended to the complete peg transfer task and other tasks of the FLS program.

References

1. Rozenblit, J. W., et al.: The Computer Assisted Surgical Trainer: Design, Models, and Implementation. Proc. of the 2014 Summer Simulation Conference, Modeling and Simulation in Medicine, pp. 211-220. (2014)
2. Nikodem, J., Wytyczak-Partyka, A., and Klempous, R.: Application of Image Processing and Virtual Reality Technologies in Simulation of Laparoscopic Procedures. In International Conference on Computer Aided Systems Theory, pp. 463-470 (2015)
3. Fundamentals of Laparoscopic Surgery, http://www.flsprogram.org
4. Hong, M. and Rozenblit, J.W.: Modeling of a Transfer Task in Computer Assisted Surgical Training. Proc. of the 2016 Spring Simulation Conference, Modeling and Simulation in Medicine, pp. 794-799. (2016)
5. Athanesious, J.J., and Suresh, P.: Systematic Survey on Object Tracking Methods in Video. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) 1, 8, pp. 242-247. (2012)
6. Hu, W., Tan, T., Wang, L., and Maybank, S.: A survey on visual surveillance of object motion and behaviors. IEEE Transactions on Systems, Man, and Cybernetics, Part C, 34(3), pp. 334-352. (2004)
7. Rogers, S., and Girolami, M.: A first course in machine learning. CRC Press, (2015)

Adaptive interface based on visual communication for users with severe disabilities

Jan Nikodem, Paweł Szczęsny, and Konrad Kluwak

Faculty of Electronics, Wrocław University of Science and Technology
11/17 Janiszewskiego, 50-372 Wrocław, Poland
jan.nikodem@pwr.edu.pl;pawelszczesny0@gmail.com;konradkluwak@gmail.com

Keywords: human-computer interactions, visual communication, intelligent image analysis, cognitive vision

Extended abstract

The contribution of this paper is to present a results of applications of cognitive informatics in creating adaptive human computer interfaces (HCI) based on visual communication and image processing. If we understand the principles of visual perception, image processing and learning processes that occur in the human brain, we can use this knowledge to improve HCI technology.

The integration of new modalities into HCI has been pursued by various researchers [?,?,?,?]. In the paper we consider visual communication and focus on face [?,?,?,?] and its elements like eyes, features, mimics and head movement.

We have investigated the human-like methods the mind uses to process information mainly for the purpose of defining assistive technology for people with severe disabilities. Although this is not an easy task, several steps of progress seem to be possible.

Firstly, the interface should be individualized. Each patient is different, moreover as a result of disease he can not adjust to a standard interface. Also different diseases [?,?,?] (aphasia, Duchenne, ALS) and their stage of progress causes another limitations of communication.

In addition, the role of HCI for handicapped people is not only to facilitate communication, but also to rehabilitate. This leading to new channels/modalities for communication and control. HCI should provide assistive procedures for people with severe disabilities. These procedures should be personalized by rehabilitation specialists who provide expert care to patients with a wide variety of medical conditions, diseases or disabilities.

In both situations mentioned above, the interface should be adaptive. When appropriate diagnosis and treatment offered by rehabilitation specialists have improved the patient's condition, it is desirable to increase requirements for the HCI. In the case of intensification of the disease, it is necessary to lower the requirements for the HCI.

Our attempt to dealing with adaptive HCI based on visual communication, has recently resulted in new methods used in modeling of such interface. We will talk about some new propositions in this field:

– striving for symmetry of the channel, the standard is that people adapt to a computer but for disabled people it must be reversed,
– how to alter the interface behavior (during its exploitation) to conform it to the people who using it?

We present sketches of what we've been doing, and some, selected aspects will be discussed on the conference.

References

1. Joseph R. M., Tanaka J. : Holistic and part-based face recognition in children with autism, J. Child Psychol. Psychiatry, 2002, p.p1-14.
2. Kazemi V., Sullivan J.: One Millisecond Face Alignment with an Ensemble of Regression Trees, Proc. of the 2014 IEEE Conference on Computer Vision and Pattern Recognition, 2014, pp. 1867-1874, ISBN 978-1-4799-5118-5, DOI 10.1109/CVPR.2014.241.
3. Papathanasiou I., Coppens P., Potagas C.: Aphasia and Related Neurogenic Communication Disorders. Jones & Bartlett Learning, 2016, ISBN 978-0-7637-7100-3.
4. Raducanu B., Vitria J.: Face recognition by artificial vision systems: a cognitive perspective; International Journal of Pattern Recognition and Artificial Intelligence, vol.22, no.5 (2008), pp.899-913, ISSN 0218-0014.
5. Szczęsny P., Nikodem J., Kluwak K.: Visual Communication in Expanding of Human-Computer Interactions, 7th IEEE Int. Conf. on Cognitive Infocommunications, CogInfoCom 2016, pp. 391-396, ISBN 978-1-5090-2643-2, Wrocław, Poland.
6. Zander T. O., Jatzev S.: Context-aware brain-computer interfaces: exploring the information space of user, technical system and environment, Journal of Neural Engineering, vol.9, no.1, , 2012 IOP Publishing Ltd.
7. Eagle eyes project, 2011, http://www.eagleeyesproject.org/.
8. b-link human-computer interface for the disabled, https://www.researchgate.net /publication/279941878_b-Link_Human-Computer_Interface_for_the_Disabled.

Performance assessment of optimal multi-objective strategy to chemotherapy treatment

Ewa Szlachcic and Ryszard Klempous

Department of Automation, Mechatronics and Control Systems,
Wroclaw University of Science and Technology, Wroclaw, Poland
{ewa.szlachcic, ryszard.klempous}@pwr.edu.pl
http://www.weka.pwr.edu.pl

Keywords: Multi-objective optimization problem, Gompertz model, differential evolution approach, Pareto set, performance assessment, chemotherapy planning

1 Introduction

The paper presents a methodology for using multi-objective differential evolutionary approach to optimize a cancer chemotherapeutic treatments. The Pareto optimal set of solutions for multi-objective optimization problem with intricate constraints was specified. The performance assessment of non-dominated solutions is discussed.

A chemotherapy is a treatment for a cancer tumor using set of toxic drugs. In a cancer chemotherapy optimization problem schedules of medical treatments were calculated based on a mathematical growth model for cancer tumor described by set of differential equations [1–6]. The minimization of tumor burden at a fixed period of time and the minimization of the toxicity of drug regimens with constraints, which described an influence of anticancer drugs for the human body, have been considered. Mathematical, Gompertz model with a liner cell-loss effect, to define a tumor growth, was used [3, 7, 4, 6, 8, 9].

The non-dominated optimal solutions set is found using modified differential evolutionary search method for multi-objective optimization problem with the help of standardization of constraints [8, 10, 11]. The drug doses should be scheduled to ensure the patients will tolerate its toxic side effects and their survival time will be longer. The search of optimization result may be very time-consuming taking under consideration the whole Pareto set of treatment scenarios. It depends on patient medical parameters and the experience of physicians.

Therefore, in the paper we try to analyse the performance of the optimal multi-objective strategies calculated as the set of non-dominated solutions, which can explore the wide range of treatment scheduling strategies [12, 13].

The performance measures [14, 15] were devised, which can gauge the quality and diversity of non-dominated solutions. Providing different drug schedules belonging to the Pareto optimal front, could be an advantage for decision-maker using proposed measures to obtain the effective chemotherapeutic treatment suggestions. A physician could assess the effectiveness of proposed drugs schedules. On the basis of assumptions concerning oncologists preferences knowledge about non-dominated front helps the decision maker in choosing the best compromise strategy for a cancer chemotherapy treatment.

References

1. Antipov, A.: Optimal multitherapy strategy in mathematical model of dynamics of the number of nonuniform tumor cells. Journal of Computer and Systems Sciences International **50**(3) (2011) 499–510
2. Antipov, A., et al.: Mathematical model of optimal chemotherapy strategy with allowance for cell population dynamics in a heterogeneous tumor. Computational mathematics and mathematical physics **49**(11) (2009) 1825–1836
3. Araujo, R.P., McElwain, D.S.: A history of the study of solid tumour growth: the contribution of mathematical modelling. Bull. Mat. Biol. **66**(5) (2004) 1039–1091
4. Chumerina, E.: Choice of optimal strategy of tumor chemotherapy in gompertz model. Journal Comput. Systems Sci. Internat. **48**(2) (2009) 325–331
5. Ledzewicz, U., Mosalman, M.S.F., Schttler, H.: Optimal controls for a mathematical model of tumor-immune interactions under targeted chemotherapy with immune boost. Discrete and Cont. Dyn. Syst.- Series B **18**(4) (2013) 1031–1051
6. Petrovski, A., Shakya, S., McCall, J.: Optimising cancer chemotherapy using an estimation of distribution algorithm and genetic algorithms. In: The Genetic and Evolutionary Computation Conference, GECCO (2006)
7. Bratus, A., Todorov, Y., Yegorov, I., Yurchenko, D.: Solution of the feedback control problem in the mathematical model of leukaemia therapy. Journal of Optimization Theory and Applications **159**(3) (2013) 590–605
8. Porombka, P.: A meta-heuristic approach for the medical treatment planning. Master's thesis, Wroclaw University of Science and Technology (2003)
9. Egorov, I.E.: Optimal feedback control in a mathematical model of malignant tumour treatment with the immune reaction taken into account. Mathematical Biology and Bioinformatics **9**(1) (2014) 257–272
10. Szlachcic, E., Klempous, R.: Differential evolution multi-objective optimisation for chemotherapy treatment planning. In: EUROCAST, Springer (2015) 471–478
11. Zaharie, D.: Differential evolution from theoretical analysis to practical insights. (2012)
12. Barry, D.W., Underwood, C.S., McCreedy, B.J., Hadden, D.D., Lucas, J.L.: Systems, methods and computer program products for guiding the selection of therapeutic treatment regimens (February 13 2001) US Patent 6,188,988.
13. Fdez-Olivares, J., Castillo, L., Cózar, J.A., Pérez, O.G.: Supporting clinical processes and decisions by hierarchical planning and scheduling. Comput. Intelligence **27**(1) (2011)
14. Ochoa, G., Villasana, M., Burke, E.K.: An evolutionary approach to cancer chemotherapy scheduling. Genetic Programming and Evolvable Machines **8**(4) (2007) 301–318
15. Zitzler, E., Thiele, L., Laumanns, M., Fonseca, C.M., Da Fonseca, V.G.: Performance assessment of multiobjective optimizers: an analysis and review. IEEE Trans. on Evolutionary Computation **7**(2) (2003) 117–132

Personalized healthcare by control engineering approaches ⋆

Levente Kovács and Imre Rudas

Physiological Controls Research Center, University Research and Innovation Center,
Obuda University, Budapest, Hungary
kovacs.levente@nik.uni-obuda.hu
rudas@uni-obuda.hu

Medical devices and computerized medical applications are exponentially increasing nowadays. This is actively supported by the EUs personalized healthcare m-Health and e-Health research programs. The core of such researches is represented undoubtedly by the basic field of biomedical engineering, the physiological modeling, simulation and control topic.

In many biomedical systems external controllers provide biosignal input or inject given specific dosage substituting the internal, physiological procedure because patients body cannot ensure it or produce it. The outer control might be partially or fully automated. The regulation has several strict requirements, but once adequately established, it permits not only to facilitate the patients life, but also to optimize (if necessary) the amount of the used dosage.

Individualized model-based control gains more and more importance in pathophysiological control. The investigated models are nonlinear and rather complex by nature. Furthermore, the parameters of the patients slowly change over time. However, despite the difficulties, the controllers have to ensure safety and stability under all circumstances. Hence, not only classical nominal control requirements, i.e. disturbance rejection, good command following and stability are required, but robust performance as well. Modern robust control methods endeavor to provide this safety, and guarantee to handle even the worst case scenario by taking neglected dynamics into account. This is done by exact mathematical formulations, but also by empiricism gained from the medical expertise of the corresponding control process. Although modern robust control theory represent linear control methods, their extension into nonlinear cases is an actively researched case as well.

At the EUROCAST 2015 conference the newly formed Physiological Controls (PhysCon) Group of the Óbuda University presented itself [1]. In the meantime, based on the obtained results the Physcon group evolved as a research center of the University Research and Innovation Center, and the current paper gives an overview of last 2 years research activities. Our researches focused on four physiological problems:

⋆ The research is supported by the European Research Council (ERC) under the European Unions Horizon 2020 research and innovation programme (grant agreement No 679681.

- diabetes, the artificial pancreas problem: we have investigated novel double diabetes model [2] and developed novel robust control solutions: LMI-based control [3], Robust Fixed Point Transformation-based control [4] and Tensor Product (TP)-based control algorithms [5];
- model-based cancer therapy: focusing on antiangiogenic targeted molecular cancer therapy we have investigated new tumor growth model possibilities [6], but discrete and nonlinear time control possibilities as well [7], [8]. Our efforts has been rewarded by an ERC Starting Grant, the most competitive and prestigious individual research grant of the EU;
- hemodialysis: we have developed a real-time industrial controller [9] and analyzed novel TP-based robust algorithms [10];
- biostatistics: we performed statistical investigations on diseases analyzing correlation of their different parameters [11]. The evidence-based medicine problem gives in this way the possibility to model the medical problem by retrospective data.

References

1. Kovács, L., Fodor, J., Ősz, R., Rudas, I., Kozlovszky, M.: Physiological Control Researches at Obuda University, In: EUROCAST 2015 Conference, pp. 127-128, Las Palmas de Gran Canaria, Spain (2015)
2. Kovács, L., Kurtán, B., Eigner, Gy., Rudas, I., Chui, C.K.: Analyzing of a Novel Time Delay Diabetes Model, In: IEEE ECC 2015 Conference, pp. 13-18, Linz, Austria (2015)
3. Eigner, Gy., Tar, J., Rudas, I., Kovács, L.: LPV-based quality interpretations on modeling and control of diabetes, Acta Polytech Hung, 13(1), 171-190 (2016)
4. Eigner, Gy, Tar, J., Kovács, L.: Fixed Point Transformation-based Adaptive Control for Type 1 Diabetes Mellitus, T Aut Contr Comp Sci, 60(74)(1), 57-66 (2015)
5. Kovács, L., Eigner, Gy.: Convex Polytopic Modeling of Diabetes Mellitus: A Tensor Product based approach, In: IEEE SMC 2016 Conference, pp. 3393-3398, Budapest, Hungary (2016)
6. Sápi, J., Kovács, L., Drexler, D.A., Kocsis, P., Gajári, D., Sápi, Z.: Tumor Volume Estimation and Quasi-Continuous Administration for Most Effective Bevacizumab Therapy, PLOS ONE, 10(11), 1-20 (2015)
7. Sápi, J., Drexler, D.A., Kovács, L.: Comparison of protocol based cancer therapies and discrete controller based treatments in the case of endostatin administration, In: IEEE SMC 2016 Conference, pp. 3830-3835, Budapest, Hungary (2016)
8. Sápi, J., Drexler, D.A., Harmati, I., Sápi, Z., Kovács, L.: Qualitative analysis of tumor growth model under antiangiogenic therapy choosing the effective operating point and design parameters for controller design, Opt Contr Appl Meth, 37, 848-866 (2015)
9. Klespitz, J., Takács, M., Rudas, I., Kovács, L.: Performance of soft computing controllers in hemodialysis machines, Int J Fuzzy Syst, 17(3), 414-422 (2015)
10. Klespitz, J., Rudas, I., Kovács, L.: TP transformation in fluid volume control for blood puri-fication therapies, In: IEEE SMC 2015 Conference, pp. 2615-2619, Hong Kong, (2015)
11. Ferenci, T., Körner, A., Kovács, L.: The interrelationship of HbA1c and real-time continuous glucose monitoring in children with type 1 diabetes, Diab Res Clin Pract, 108(1), 38-44, (2015)

Automated health state assessment using sensory data

Miklos Kozlovszky, Levente Kovács, Imre Rudas

EKIK, Óbuda University, Budapest, Hungary
{kozlovszky.miklos, kovacs.levente}@nik.uni-obuda.hu, rudas@uni-obuda.hu

Abstract. Health state assessment is a complex task. Vital sign monitoring in hospitals or at ICU (intensive care unit) acquire usually small and definite number of parameters. However biosignal acquisition using wearable sensors enables us to monitor remotely a vast amount of various vital signs/life signals from a large population easily. With recent telemedicine solutions a single practitioner can monitor the vital parameters of hundreds of patients in real time, up to several days or months. The large number of data sources multiplied by the number of modalities, with high sampling rates can produce huge data quantities (so called Big Data problem), what could be difficult to transmit, to process, to analyze, to visualize or even to store as relevant data. Additionally multi-sensor data processing requires complex solutions for data representation, sensor value normalization and sensor data fusion. In this paper we are proposing a new way to assess automatically the personal health state from various sensor modalities. The same approach enables us to do also population scale health state assessments.

1 Introduction

Population health state assessment, or even the health state assessment of a single person is a complex task [1, 3, 5].Vital sign monitoring in hospitals or at ICU (intensive care unit) acquire usually small and definite number of parameters [2]. However biosignal acquisition using wearable sensors enables us to monitor remotely a vast amount of various vital signs/life signals from a large population easily. [1]Remote

[1] The projects have been supported by the European Union. The authors would like to thank GOP-1.1.1-11-2012-0055- DIALOGIC: Mathematical model based decision support system for diabetes monitoring, for its financial support. The authors would like to thank PPT Ltd. for their research support many advises and useful contributions.

patient monitoring has several advantage properties, just to name a few: the patient is monitored location independently; multiple modalities can be used for monitoring; patients can be monitored during their everyday life in their normal environment. Data acquisition systems can effectively collect the monitored sensor data and transfer to remote locations. Sensors are providing raw data, so the pre-processing and data filtering are important steps to build up the DIKW (data-to-information-to-knowledge-to-wisdom) pyramid. Data processing is a key part of all the monitoring systems, thus all evaluation and knowledge extraction, furthermore the alarming services based on that too. Large scale sensor networks are producing vast amount of data thus multi-layered approaches needed for data processing. The first layer of data processing has multiple sub-layers: the basic sub-layer handles single source, primitive data types (integers, float, double, etc.) and provides range focused evaluation; the second sub-layer of data processing is targeting the complex data types (e.g.: ECG, EEG curves), where complex pattern searching is required. The second layer of data processing is used by trend analysis using calculation of derivatives in higher dimensions. The next layer of data processing targets multi-source sensor data. Our new dynamic personal health state model is able to capture and incorporate real-time biosignal data acquired during remote patient monitoring. This model builds up from a vast amount of acquired/digitalized data defined as a parameter value (e.g.: body weight, blood glucose level, or pulse). The acquired sensor data define the patient's state model dimensions in the information space (called as HM space) [4]. After the acquired sensor data converted to the HM space its visualization, and trend analysis is straight forward. The dynamic personal health state model defines HM space, which is clustered to 12 major HM sectors. The acquired sensor parameters can be allocated into one of the HM sectors. And the numerical value of the j-th HM sector can be calculated as follows:

$$HM_j = \sum_{l=1}^{N_K} S_l * w_l \qquad (1)$$

, where $$\sum_{l=1}^{N_K} w_l = 1 \qquad (2)$$

where N_K is the total number of different parameter sets within the j-th sector, S_l is the calculated health state value, and w_l is pre-defined weight factor belongs to the S_l.

2 Population scale health state assessment calculation

After the patient level data processing finished, the acquired data can be aggregated and analyzed at population scale. A dynamic population state model can be defined from the individual health state models as follows: The average value of the (*) population health state parameter value $PS_{*\text{-}AVG}$ can be defined as:

$$PS_{*-AVG} = \frac{\sum_{j=1}^{Q*} S_j}{Q*} \qquad (3)$$

, where Q_* is the size of the analyzed (*) population (can be a sub-set of the full population, which is filtered by the * parameter) and S_j is the health state parameter value of an individual from the population. The $PS_{*\text{-}AVG}$ can be used to visualize as a distribution curve how the analyzed population average is changing during time. On the distribution curve can be easily captured how the highlighted parameter is changing versus time within the analyzed population (can be used as indicator to track how the healthy and non-healthy categories evolving). This distribution curve can be effectively used for prevention, statistics, and for health care service planning or health care resource allocation.

Similar way can be calculated the first quartile and the third quartile of the population health state parameter value set. Furthermore the *j*. Population HM space (PHM) space segment of a targeted (*) population can be defined as follows:

The total sum of *j*. HM space segment of each individuals from the population normalized by Q_* the size of the population.

$$PHM_{j*} = \frac{\sum_{i=1}^{Q*} HM_{ji}}{Q_*} = \frac{\sum_{i=1}^{Q*}(\sum_{l=1}^{N_K} S_l * w_l)}{Q_*} \qquad (4)$$

The health state parameter value of an individual can be compared to the population level health state parameter value. To have meaningful comparison usually only a subset of the population is used (as an example: 40 years old male population:

$$PS_{40M-AVG} = \frac{\sum_{j=1}^{Q_{40M}} S_j}{Q_{40M}} \qquad (5)$$

Similar way the aggregated individual HM space sector values can be compared with the PHM (Population HM) space value. Thus the distance between the individual values and the population scale average values can easily calculated and assessed:

$$\Delta S_l = S_l - PS_{l*\text{-}AVG} \qquad (6)$$

$$\Delta HM_j = HM_j - PHM_{j*\text{-}AVG} \qquad (7)$$

The dynamic change rate of S_l can indicate how balanced the person's health state is, and the direction of the change can be also easily monitored. At population level the usage of HM space enables more accurate population scale health state assessment.

3 Visualization of the population's health state structure

Health state structure of the population refers to the age and health status of a population. The health status values can be combined with population pyramids to create a population health pyramid, which is a graphical illustration that shows the distribution of health state of various age groups in a population (typically that of a country or region of the world). Thus can also used to determine and graphically visualize the overall health state distribution of a population.

4 References

1. Kozlovszky, M.; Bartalis, L.; Jokai, B.; Ferenczi, J.; Bogdanov, P.; Meixner, Zs.; Nemeth, L.; Karoczkai, K., Personal health monitoring with Android based mobile devices, Information and Communication Technology Electronics and Microelectronics (MIPRO), 2013 36th International Convention on , vol., no., pp.326,330, 20-24 May 2013
2. Malcolm Elliott and Alysia Coventry; Critical care: the eight vital signs of patient monitoring; CRITICAL CARE, British Journal of Nursing, 2012, Vol 21, No 10, pp.: 621-625
3. M. Kozlovszky, J. Sicz-Mesziar, J. Ferenczi, J. Marton, G. Windisch, V. Kozlovszky, P. Kotcauer, A. Boruzs, P. Bogdanov, Zs. Meixner, K. Karoczkai, S. Acs, Combined Health Monitoring and Emergency Management through Android Based Mobile Device for Elderly People; K.S. Nikita et al. (Eds.): MobiHealth 2011, LNICST 83, pp. 268-274, 2012. Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2012
4. M. Kozlovszky, Multi-parameter health state assessment, Bioinspired Intelligence (IWOBI), 2015 4th International Work Conference on, San Sebastian, 2015, pp. 145-150., doi: 10.1109/IWOBI.2015.7160158
5. M. Kozlovszky, L. Kovacs, K. Karoczkai; Cardiovascular and diabetes focused remote patient monitoring; VI Latin American Congress on Biomedical Engineering CLAIB 2014, Parana, Argentina 29, 30 31 October 201, Vol. 49 IFMBE Proceedings, Braidot, Ariel, Hadad, Alejandro, Springer International Publishing, ISBN 978331913116-0, DOI: 10.1007978-3-319-13117-7123; pp: 568-571

Enabling Design of Biomimetic Middleware for Large Scale IOT-based CyberMedical Systems

Zenon Chaczko[1], Ryszard Klempous[2] Lucia Carrion Gordon[3],

[1,2,3] Faculty of Engineering and Information Technology,
University of Technology Sydney, NSW, Australia
[2]Faculty of Electronics, Wroclaw University of Technology, Wroclaw, Poland
{zenon.chaczko@uts.edu.au, ryszard.klempous@pwr.wroc.pl, lucia.carrion@uts.edu.au}

Abstract: In recent years the Internet of Things (IoT) technology has matured to a point where it is feasible to discover, locate and identify various smart sensors and devices based on the context, situation, their characteristics and relevancy in order to query for their data or control actions. Taking things a step further when developing Large Scale Applications requires to overcome two serious issues. The first issue is find a solution for data sensing and collection from a large number of various ubiquitous devices when converging these into the next generation networks. The second important issue is to deal with the "Big Data" that arrive from a very large number of sources. This research emphasizes the need for finding a solution for a massive scale data aggregation and delivery. The paper introduces biomimetic design methods for data aggregation in the context of large scale IoT-based CyberMedical applications.

Keywords: Biomimetics, Middleware for Ubiquitous Systems, the Internet of Things, CyberMedical Systems

1 An Overview of IOT Concepts

The IOT domain represents some of the greatest research challenges and opportunities that have appeared in recent years. New emerging technologies related to the wireless smart sensor and actuators, autonomic computing [1], Artificial Intelligence (AI), middleware [2], communication systems and protocols, engineering standards and the next generation networks are leading to a new paradigm where sensors and actuators can be treated as a common infrastructure with an ability to provide multiple and concurrent services, smart data aggregation to variety of end users [3-4]. This approach differs with the concept of dedicated devices being physically and logically fixed within the dedicated computing and telecommunication infrastructure. Significant research work still needs to be done to adapt modern middleware models, protocols and standards, data aggregation and sensor fusion methods as well as the data delivery mechanisms in order to modify the way IOT devices could become an integral part of a common public infrastructure. One of the

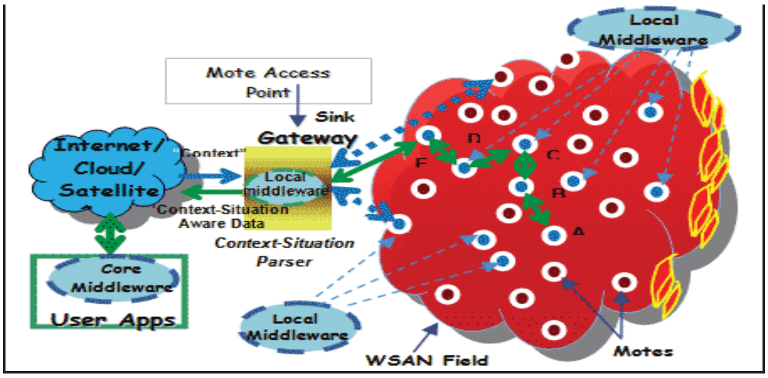


Figure 1: Middleware for the IoT-based System

key issues to be solved in the presented work is to provide a feasible architectural model for design and implementation of a new type of software infrastructure that is referred to as a biomimetic model of middleware (BMM) [5]. A typical topology and localisation of middleware components in IoT- based software application is depicted in Fig 1. In IoTs, the Mote Access Point devices can play dual roles: these devices are data sinks for sensors and a control sinks for actuators that form segments of the IoT. MAP devices represent intelligent gateways that host contextual-situation data processors/parsers at the boundary of sensor/control of IoTs.

In this research, a new paradigm of biomimetic middleware for IoT-based systems is introduced, together with the supporting adaptive data aggregation models. The biomimetic middleware allows a new generation of multi-purpose sensor-actuator networks and services to become a viable solution. This research work discusses various challenges for IoT middleware. Innovations involve the vision for the advanced of large scale, software intensive health care systems. This work is organized into 5 sections. After the introduction, section 2 describes a new biomimetic model of middleware (BMM) and reviews adaptive data aggregation techniques. Section 3 describes design aspects of biomimetic middleware solution that can enable the development and deployment of secure, context aware, heterogeneous, flexible and large-scale applications. Section 4 illustrates the feasibility of implementing a biomimetic middleware for a large-scale IOT based system.

References

1. Bantz D. F. et al, (2003) Autonomic personal computing, Autonomic Computing, Vol. 42, Number 1.
2. Britton C., Bye P. (2004) “IT Architectures and Middleware: Strategies for Building Large, Integrated Systems”, Addison Wesley Professional.
3. Chaczko, Z.; Chiu, C.; Aslanzadeh, S.; Dune, T. (2011), Software Infrastructure for Wireless Sensor and Actuator Networks, Proceedings of 21st International Conference on Systems Engineering, ICSEng2011, Las Vegas, pp.474–479.
4. Chaczko, Z.C. & Aslanzadeh, S. (2011), 'C2EN: Anisotropic Model of Cloud Computing', International Conference on Systems Engineering, Proceedings of 21st Intl Conference on Systems Engineering, ICSEng 2011, Las Vegas, USA, pp.467-473.
5. Chaczko, Z., (2009) “Towards Epistemic Autonomy in Adaptive Biomimetic Middleware for Cooperative Sensornets”. PhD thesis, University of Technology, Sydney, Australia, July 2009.

Anticipating the Unexpected: Simulating a Health Care System Showing Counterintuitive Behavior

Markus Schwaninger, University of St. Gallen, Switzerland
Dufourstrasse 40a, 9000 St. Gallen, Switzerland
markus.schwaninger@unisg.ch

Extended Abstract

The behavior of complex systems is often counterintuitive. The idea of anticipating the unexpected challenges commonsense. The purpose of this contribution is to demonstrate the power of modeling and simulation in discovering the structures, which generate counterintuitive behavior (Forrester 1971) in organizations. The research question here is if and how this kind of insight in the generative "mechanisms" of unexpected behavior can be achieved. If it can be obtained, then unexpected events become amenable to being anticipated in the sense of contingencies. To answer our research question, we revert to a case study of a health-care system showing unexpected behavior.

In organizations, unexpected things happen all the time. It seems paradoxical to claim that one can anticipate the unexpected: One cannot anticipate something unexpected. So much for the commonsense understanding.

Our claim is that unexpected behavior can be anticipated by good models with the help of simulation. Our argument is based on two phases of modeling, first conceptual-qualitative and then mathematical-quantitative. We apply System Dynamics, a widely used methodology for the modeling and simulation of complex dynamic systems.

A case study is used to underpin our claim. The study was realized in the health care system of Carinthia, a nation-state of the Republic of Austria. The full case study covering 30+ years, is documented elsewhere (Schwaninger & Klocker 2017). In this piece, we concentrate on the last phase of the case study (2011-2015), and elaborate on aspects pertinent to the purpose of this contribution: to use modeling and simulation for the anticipation of unexpected behavior of complex systems. We are focusing on organizations, but in principle our study is relevant for any kind of social system.

Case Study

The scenery of our case study is the Oncological Care System (OCS) of Carinthia, with its hub at the central hospital of Klagenfurt, the capital. This is an efficient unit. The employs around 30 persons, who process about 2’000 cases a year. In 2010, the OCS showed a record of continual successes, which had been achieved in its history since 1985. However, 25 years after the foundation of the unit, in 2011, the administration of the central hospital announced that it would cut the budgets of all departments, “… to improve the economic situation”. The leaders of the OCS made a rough estimate: such a cut would reduce their financial resources available severely.

To analyze the situation more closely, a simulation model was built cooperatively: the oncologists contributed the substantive knowledge about the issues under study, while the author (MS) furnished modeling and simulation know-how. The purpose of the model was to anticipate what the implications of the announced cut in the budget would be. In a first phase, a qualitative analysis by means of causal-loop diagrams was carried out. In the second phase, a quantitative simulation on the basis of System Dynamics was built and validated. In the third phase, scenarios were accomplished and policies were tested. We analyze the procedures of all three phases. Finally, the results of the simulations are compared with data of the “real world”.

Results

The results of the simulations unveiled clear patterns of the OCS’s behavior, some of which were unexpected. The simulation model is a holistic representation of the issue under study, and the results convey the consequences produced by that issue. Model analysis then uncovers the generative “mechanisms”: structures that bring forth specific kinds of behavior patterns.

In this contribution, dynamic simulation has been explored as an instrument, by means of which the counterintuitive, unexpected outcomes of certain policies or interventions can be anticipated. The structural features of our model are of a generic type. In other words, they are applicable to multiple contexts, representing a “wider class” of real-world situations (Forrester 1961: 208). Hence, their applicability is not limited to public organizations, but it also covers private firms.

References

Forrester, J. W. (1961). Industrial Dynamics. Cambridge, MA: MIT Press.

Forrester, J. W. (1971). Counterintuitive Behavior of Social Systems. Technology Review 73(3): 52-68.

Schwaninger, M. and J. Klocker (2017). Efficiency versus Effectiveness in Hospitals: A Dynamic Simulation Approach. Outcome-Based Performance Management in the Public Sector. Eds. E. Borgonovi, E. Anessi Pessina, and C. Bianchi. Forthcoming.

Inscrutable Decision Makers: Knightian Uncertainty in Machine Learning

Rick Hangartner and Paul Cull

Computer Science
Kelly Engineering Center
Oregon State University
Corvallis, OR 97331
hangarr09@gmail.com
pc@eecs.oregonstate.edu

DATA, DATA, DATA!

Big data and machine learning will solve our problems, Or Will It?

Machine learning (ML) practitioners use data to build statistical models which they hope will allow them to make predictions about the properties of unobserved individuals (or missing attributes of observed individuals) who are assumed to be from the same population that generated the data. Econometricians, on the other hand, use data to build causal models. They hope to predict the change, usually averaged over the population, in the outcome variable due to a change in the causal variable. Both communities have to deal with both quantifiable uncertainty (risk), and unquantifiable Knightian uncertainty (ambiguity).[5] Thirty years ago Leamer [6] brought this distinction to the attention of economists. Recent claims by Angrist and Pischke's [4] for the vast improvements in causal models due to advances in modeling and BIG data/ML work techniques has again raised the issue that these techniques do not deal meaningfully with Knightian uncertainty (ambiguity) [7].

In this paper we present a data model we dub the *Inscrutable Decision Maker* (IDM) that postulates observed data arises as a unquantifiable choice from amongst multiple unobservable probabilistic data generating sources. Our motivating contention is that while one can statistically model the observed data *ex post*, any *ex ante* forecasting model must acknowledge non-probabilistic ambiguity in some fashion. From our perspective, both econometricians and ML practitioners face the twin tasks of identifying the multiple unobservable data models and the ambiguity in the observable data.

We derive our data model from the Anscombe-Aumann model of subjective utility [1], [3]. Using a formalism for ambiguity abstracted from Ellsberg's Paradoxes [2], we construct a compact description for non-deterministic decisions and the resulting ambiguous data that combines the individual probabilities of unambiguous alternatives with the total probability of ambiguous alternatives.

We then relate our data model to marginal models for populations by averaging out ambiguity and to conditional models using ambiguity to differentiate individuals. Finally we present an example computational algorithm for logistic regression models.

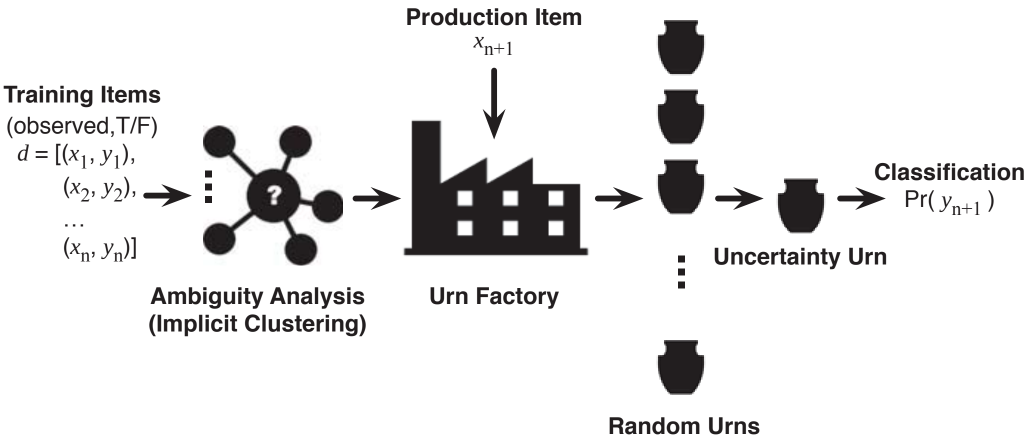


Fig. 1. The Inscrutable Decision Maker Model

References

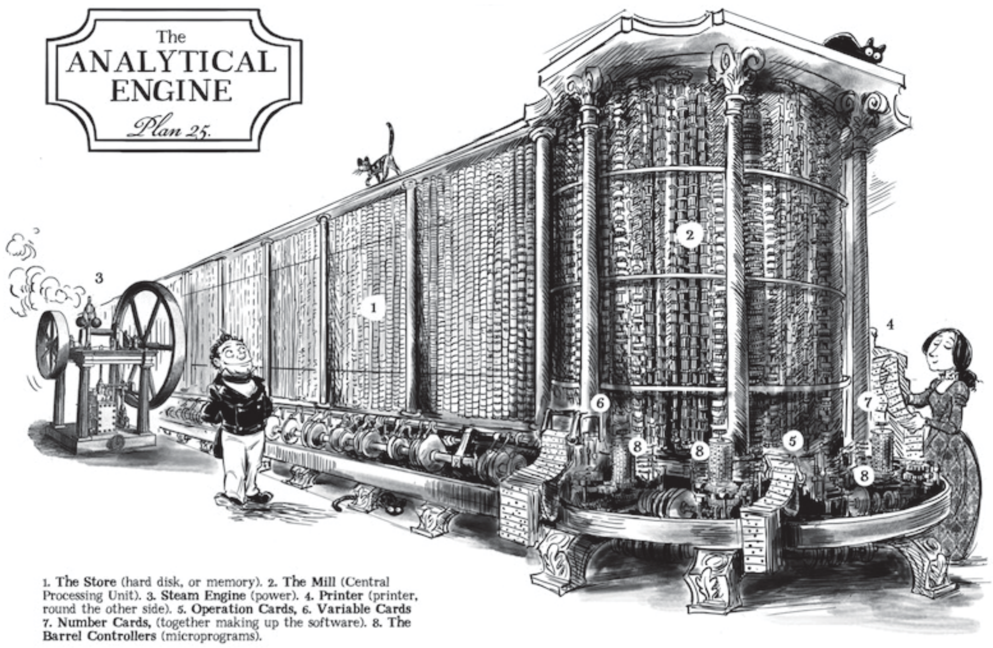
1. Anscombe, F.J., Aumann, R.J.: A Definition of Subjective Probability. The Annals of Mathematical Statistics 34(1), 199–205 (1963), https://dx.doi.org/10.1214/aoms/1177704255
2. Ellsberg, D.: Risk, Ambiguity, and the Savage Axioms. Quarterly Jour. of Economics 75(4), 643–669 (1961), https://dx.doi.org/10.2307/1884324
3. Gilboa, I., Marinacci, M.: Ambiguity and the Bayesian Paradigm. In: Arló-Costa, H., Hendricks, F.V., van Benthem, J. (eds.) Readings in Formal Epistemology: Sourcebook, pp. 385–439. Springer International Publishing, Cham (2016), http://dx.doi.org/10.1007/978-3-319-20451-2_21
4. Joshua Angrist and Jörn-Steffen Pischke: The Credibility Revolution in Empirical Economics: How Better Research Design Is Taking the Con Out of Econometrics. Journal of Economic Perspectives 24(2), 3–30 (2010)
5. Knight, F.H.: Risk, Uncertainty, and Profit. Hart, Schaffner & Marx, Houghton Mifflin Company (1921)
6. Leamer, E.E.: Let's Take the Con Out of Econometrics. American Economic Review 73(1), 31–43 (1983)
7. Leamer, E.E.: Tantalus on the Road to Asymptopia. Journal of Economic Perspectives 24(2), 31–46 (2010), http://dx.doi.org/10.1257/jep.24.2.31

The Computer and the Calculator

Paul Cull

Computer Science
Kelley Engineering Center
Oregon State University
Corvallis, OR
97331, USA
pc@cs.orst.edu

Some recent discussions have suggested that the the concept of universal stored program computer is not useful in understanding the history of computing. In particular, there is the suggestion that this idea was so well known that all of the early computing devices already incorporated this concept. We review the design of several early machines. We argue that all or almost all of the early digital machines were based on the idea of a **calculator** and that the **computer** was a real and significant new concept. We attempt to explain the differences between **calculator** and the **computer**, and try to show that our contemporary computing is based on the **computer** rather than the **calculator**, and that the calculator model is inadequate to describe our current notions of computing.



Trends in Non-email Spam and Non-email Spam Filters. An Overview

Ylermi Cabrera-León[1], Patricio García Báez[2], and Carmen Paz Suárez-Araujo[3]

[1] Universidad de Las Palmas de Gran Canaria (ULPGC), Las Palmas de Gran Canaria, Spain
[2] Departamento de Ingeniería Informática y de Sistemas, Universidad de La Laguna, San Cristóbal de La Laguna, Spain
[3] Instituto Universitario de Ciencias y Tecnologías Cibernéticas, ULPGC, Las Palmas de Gran Canaria, Spain
ylermi.cabrera101@alu.ulpgc.es, pgarcia@ull.es, carmenpaz.suarez@ulpgc.es

Keywords: Spam filtering · Non-email spam · Social spam · SMS spam · Spim · Adversarial Machine Learning

Extended Abstract

The socio-economic aspects of Instant Messaging (IM) (WhatsApp, Windows Live Messenger…), Short Messaging Service (SMS) and social media (*e.g.* Facebook, Twitter, etc) have been severely affected by spams received through them. Indeed, they have become a serious security risk, especially for embedded systems.

Electronic spam, or unsolicited messages sent massively, is one of the threats that affects email and other media [2]. Several terms have been coined for these non-email spams: "instant spam" or "spim" refers to spam via IM, "mobile spam" for SMS spam, and "social spam" if received through social media. During the last four decades its high volume, especially of email spam, have produced exorbitant economic and time losses. For this reason, many diverse anti-spam techniques have been deployed, which filter distinct characteristics of spam, working at different levels and based on a number of procedures. The appearance of newer filters stimulated the adaptation of both spams and spamming strategies, and *vice versa*. This never-ending process has been called "spam arms race", and considered an example of coevolution or reactive adversarial Machine Learning (ML).

The efficacy and complexity level of anti-spam filters have been high enough to stop most unwanted messages and to slow down spammers' counterattacks. Due to this, the overall spam volume has decreased from 92.6% in 2008 [6] to around 50% as of June 2016. Moreover, the Global Financial Crisis of 2007-2009, the takedowns of many spamming botnets, and the migration of the spam business to other more profitable and less monitored techniques (*e.g.* ransomware, phishing…) or electronic media explain this drop too.

Related with the latter, although the quantity and proportion of non-email spams are still not as massive as those of email ones, they are constantly growing: 500 million instant spams in 2002-2003 [5]; during 2011 up to 30% of all SMS traffic in China and India was mobile spam [3]; and Facebook blocked daily 200 million harmful activities and hosted 14.3 million undesirable and potentially dangerous fake accounts in August 2012 [4].

Initially, non-email spam filters lacked technological complexity, being limited to prevention, technological education of users, legislation and law enforcement agencies. They are still the most recommended due to their effectiveness. Later on, some filters adapted from email spam ones appeared, even though these media are based on dissimilar technologies and fulfill even antagonistic requirements. At first, collaborative and less automatic techniques were adapted, such as user feedbacks, challenge-response, whitelists and blacklists. More recently, approaches based on ML began to be implemented, being the most used Bayesian methods, focusing in Naïve Bayes-based filters; Support Vector Machines; Artificial Neural Networks, from paradigmatic neural architectures to deep learning schemes; and decision trees. These three groups are usually combined in order to overcome some non-email spam filtering difficulties: usage of Internet slang or SMS language, which likely requires anti-obfuscation methods [1]; small-sized messages... On the other hand, so far not as many filters not adapted from email ones exist.

In this paper the characteristics of non-email spam - focusing on IM, SMS and social media - are described and compared with those of email spam. Additionally, the trends in non-email spam that have appeared in the last decade and the spammers' countermeasures to the preceding filters, if any, are introduced. After that, an overview of the state-of-the-art filters for non-email spam is presented. Among them, our proposal of a hybrid anti-email-spam, which can be adapted to filter non-emails, is explained [1]. It is based on Self-Organizing Maps, an unsupervised neural architecture, and thematic categories, and it includes an important anti-obfuscation feature.

References

1. Cabrera-León, Y., García Báez, P., Suárez-Araujo, C.P.: Self-Organizing Maps in the Design of Anti-spam Filters. A Proposal based on Thematic Categories. In: Proceedings of the 8th IJCCI 2016. vol. 3: NCTA, pp. 21–32. SCITEPRESS Digital Library, Porto, Portugal (Nov 2016)
2. Chakraborty, M., Pal, S., Pramanik, R., Ravindranath Chowdary, C.: Recent developments in social spam detection and combating techniques: A survey. Information Processing & Management (May 2016), http://linkinghub.elsevier.com/retrieve/pii/S0306457316300966
3. Delany, S.J., Buckley, M., Greene, D.: SMS spam filtering: Methods and data. Expert Systems with Applications 39(10), 9899–9908 (Aug 2012), http://linkinghub.elsevier.com/retrieve/pii/S0957417412002977
4. Kelly, H.: 83 million Facebook accounts are fakes and dupes (Aug 2012), http://www.cnn.com/2012/08/02/tech/social-media/facebook-fake-accounts/index.html
5. Liu, Z., Lin, W., Li, N., Lee, D.: Detecting and filtering instant messaging spam - a global and personalized approach. In: 1st IEEE ICNP Workshop on Secure Network Protocols, 2005. (NPSec). pp. 19–24. IEEE (Nov 2005), http://ieeexplore.ieee.org/document/1532048/
6. Statista: Global spam volume as percentage of total e-mail traffic from 2007 to 2015 (Apr 2016), http://www.statista.com/statistics/420400/spam-email-traffic-share-annual/

Using System Dynamics and Network Controllability

Lukas Schoenenberger[1], Radu Tanase[2], Andrea Schenker-Wicki[1]

[1]Faculty of Business and Economics, University of Basel, Switzerland

lukas.schoenenberger@unibas.ch

[2]URPP Social Networks, University of Zurich, Switzerland

radu.tanase@business.uzh.ch

Extended Abstract

System dynamics (SD), an approach to modeling and simulating complex systems, has repeatedly demonstrated its value in contributing to the understanding and solution of complex policy problems—most notably in areas such as public health, energy and the environment, social welfare, sustainable development, and security [1, 2]. One of the main challenges in system dynamics is that, due to a high degree of interdependent model variables and nonlinear relationships, the detection of model levers, i.e. variables capable of effectively and efficiently controlling complex policy problems, is exceedingly demanding. So, notwithstanding the usefulness of system dynamics in the analysis of these problems, the solution identification process is far from straightforward and in most cases trial-and-error driven [3, 4]. To address this challenge, we propose to combine system dynamics with network controllability to facilitate the detection of model levers. Network controllability emerged only recently in the wider field of network science that is currently dominating the analysis of complex systems. Network controllability specifies our ability to steer a dynamical system from any initial state to any desired final state in finite time using appropriate inputs [5]. So how can system dynamics be merged with network controllability?

In essence, a system dynamics model can be thought of a web of interrelated causal factors that are assumed giving rise to the complex policy problem under study. Due to its web similarity, the structure of a system dynamics model can be accurately described as a directed weighted network, making it accessible to algorithmic exploration using concepts from the fields of graph theory and network science [6–8]. Referring to recent research on control principles of complex networks, model levers are found first by calculating the size of the minimum driver set of the system dynamics model (network), second by computing all existing minimum driver sets, and third by ranking minimum driver set variables according to their control centrality [9]. Variables with a high control centrality should be of primary interest to policy-makers when designing new solutions to complex policy problems. We demonstrate the proposed multimethodological approach on the basis of the World Dynamics model, a classic example from the system dynamics literature [10].

1. Ghaffarzadegan, N., Lyneis, J., Richardson, G.P.: How small system dynamics models can help the public policy process. Syst. Dyn. Rev., n/a-n/a (2010)
2. Sterman, J.D.: Business Dynamics: Systems Thinking and Modeling for a Complex World. McGraw-Hill Higher Education, Boston, MA (2000)
3. Oliva, R.: Structural dominance analysis of large and stochastic models. Syst. Dyn. Rev. 32, 26–51 (2016)
4. Forrester, J.W.: System dynamics, systems thinking, and soft OR. Syst. Dyn. Rev. 10, 245–256 (1994)
5. Liu, Y.-Y., Slotine, J.-J., Barabasi, A.-L.: Controllability of complex networks. Nature 473, 167–173 (2011)
6. Schoenenberger, L., Schmid, A., Schwaninger, M.: Towards the algorithmic detection of archetypal structures in system dynamics. Syst. Dyn. Rev. 31, 66–85 (2015)
7. Oliva, R.: Model structure analysis through graph theory. Partition heuristics and feedback structure decomposition. Syst. Dyn. Rev. 20, 313–336 (2004)
8. Kampmann, C.E.: Feedback loop gains and system behavior (1996). Syst. Dyn. Rev. 28, 370–395 (2012)
9. Liu, Y.-Y., Slotine, J.-J., Barabasi, A.-L.: Control centrality and hierarchical structure in complex networks. PloS one 7, e44459 (2012)
10. Forrester, J.W.: World Dynamics. Wright-Allen Press, Cambridge, Massachusetts (1971)

Telematics Solution for Optimal Passenger Distribution at Metro Stations

Jusuf Çapalar, Aleksander Nemec, Christoph Zahradnik
and Cristina Olaverri-Monreal

University of Applied Sciences Technikum Wien, Department of Information Engineering and Security, Höchstädtplatz 6, 1200 Vienna, Austria

{jusuf.capalar, aleksander.nemec, christoph.zahradnik}@gmail.com, olaverri@technikum-wien.at

Abstract. To alleviate overcrowding on the most popular subway lines and specific trains, especially during rush hours, we propose a system to optimize passenger distribution. Through visual cues directly displayed on the waiting platform, travelers are informed about the occupation rate in carriages so that they can make a decision about which to use before the train arrives. The system evaluation indicated the relevance of the implementation for both travelers satisfaction as well as for train operators.

Keywords: Metro Stations, Passenger Distribution

1 Introduction

The trend of population growth in cities demands consideration of more efficient subway management systems that alleviate overcrowding on popular trains and subway lines, especially during the busiest travel times. Several works have shown that the position and number of platform exits/entrances has a significant influence on passenger distribution [1], [2]. As stated in [3], a station with several platform entrances resulted in a more balanced passenger distribution. Uneven distribution causes delays for trains when the operator needs to allow extra time for boarding, resulting in longer waiting times for passengers. In order to alleviate this situation, passengers waiting on the train platform should be directed to doors where there are less people waiting to board, thereby orienting themselves better before the train arrives.

2 Technical Implementation

We propose in this paper a system that displays the available places at each carriage before the train arrives. We implied the number of passengers calculating the weight of each carriage via a control system before the train leaved the previous station. This number was then broadcast to the next station. A model was then built in order to calculate the passenger distribution in one carriage in real time. For the remaining set of carriages we implemented a software system that generated a random distribution. An ultrasonic sensor acquires the real time data from the center-line distances to determine the carriage load through an Arduino UNO board that was connected to a laptop. In addition, a Java program was developed to evaluate the measured values. The program graphically simulated a subway station and showed the optimum distribution of passengers through the control system indicating entrances with less occupancy rate determining the distance between the undercarriage of the subway train and its axis. From the measured distance we could infer the degree of capacity utilization of the carriage. The measuring time corresponds to the period of time before the departure during which the passengers are aboard and the door of the train closed.

3 Results

The control system with maximum ease of use was determined by a survey. The participants had to answer relevant questions and choose between four different graphic control systems. According to the results 75% of the respondents would use a similar control system to that proposed in this paper.

References

1. D. Szplett and S. Wirasinghe, "An investigation of passenger interchange and train standing time at LRT stations:(i) alighting, boarding and platform distribution of passengers," *J. Adv. Transp.*, vol. 18, no. 1, pp. 1–12, 1984.

2. Y. Wu, J. Rong, Z. Wei, and X. Liu, "Modeling Passenger Distribution on Subway Station Platform prior to the Arrival of Trains," presented at the Transportation Research Board 91st Annual Meeting, 2012.

   N. Krstanoski, "Modelling Passenger Distribution on Metro Station Platform," *Int. J. Traffic Transp. Eng.*, vol. 1, no. 4, pp. 456–465, 2014.

Online Traffic Management System (OTMS): Vehicle Counting via Computer Vision

Arman Allamehzadeh, Mohammad. S Aminian,
Mehran Mostaed and Cristina Olaverri-Monreal

University of Applied Sciences Technikum Wien, Department of Information Engineering and Security, Höchstädtplatz 6, 1200 Vienna, Austria

{arman4u, mehran.mostaed7}gmail.com,
m.s.aminian@hotmail.com, olaverri@technikum-wien.at

Abstract. Technology based on sensors or cameras that is related to the field of Intelligent Transportation Systems (ITS) can help to alleviate road congestion problems by collecting and evaluating real time traffic data. In this paper, we present an approach to counting vehicles in target roads that are equipped with cameras. The implemented software is capable of working in different streets and makes later statistical analysis of the data possible.

Keywords: Vehicle Counting, Computer Vision

1 Introduction

Technology based on sensors or cameras that is related to the field of Intelligent Transportation Systems (ITS) can help to alleviate road congestion problems by collecting and evaluating real time traffic data [1, 2]. In this paper, we present an approach to counting vehicles in target roads that are equipped with cameras. Relying on the EmguCV library for image processing and .NET technologies information, image and time data is collected and sent to a server. This approach makes later statistical analysis of the data possible.

2 Technical Implementation

The implemented software is capable of working in different streets but the camera angle is important for accurate detection of moving vehicles. A camera for each side of the street was required, regardless of the number of lanes. We processed the images in as follows:

The implemented system started to receive a video stream provided by either alive camera or by a recorded video (e.g. by CCTV). For cost-saving and performance reasons, all the frames were in gray scale. After receiving the data, image processing was initiated. This phase consisted of the following three blocks:

- Background building. The background was determined by comparing sequential series of frames and averaging them by OpenCV functions to create a scene with no vehicle.
- Filtering and comparison of two sequential frames. Comparison points for two sequenced frames were determined and a threshold was calculated that enabled the detection of such a frame with distinct black/white contrast. The resulting image noises from this operation were then reduced by using Gaussian Blur noise filters.
- Movement detection. Having subtracted the background from the threshold frame, we obtained a new frame that was composed of moving contours. We then determined the contours that shaped the vehicle.

After having obtained the information related to the time stamp, scene image, and plate number we stored it in a database and repeated all the above mentioned steps until having received the stop command.

3 Evaluation

We evaluated the implemented system by examining the received video stream provided by a recorded video file [3] under daylight conditions. After solving problems related to the duplicated detection of the same vehicle in two different scenes a rate of 90% detections in a short period of time could be established.

References

1. C. Olaverri-Monreal, “Automated Vehicles and Smart Mobility Related Technologies,” *Infocommunications J.*, Aug. 2016.

2. J. Goncalves, J. S. Goncalves, R. J. Rossetti, and C. Olaverri-Monreal, “Smartphone sensor platform to study traffic conditions and assess driving performance,” in *17th International Conference on Intelligent Transportation Systems (ITSC)*, 2014, pp. 2596–2601.

3. C. Dahms, “MicrocontrollersAndMore.” https://github.com/MicrocontrollersAndMore

Approaching Emergency Vehicle Warning (AEVW)

Mehran Mostaed, Khaled Aldabas, and Cristina Olaverri-Monreal

University of Applied Sciences Technikum Wien, Department of Information Engineering and Security, Höchstädtplatz 6, 1200 Vienna, Austria

{mehran.mostaed7,kahled.aldabbas}@gmail.com, olaverri@technikum-wien.at

Abstract. Intelligent Transport System applications are supported by systems relying on Dedicated Short-Range Communications (DSRC). This paper presents the implementation steps for a vehicle to vehicle (V2V) communication system that intends to increase driver awareness of the surroundings in an emergency situation. Particularly, the system broadcasts basic safety warning messages between an emergency vehicle and other vehicles in the vicinity.

Keywords: Vehicle-to-Vehicle communication, Emergency Warrning System, DSRC

1 Introduction

Cooperative Intelligent Transport Systems and Services (C-ITS) enable wireless communication between vehicles and/or traffic infrastructure using a standardized set of messages that are based in the transfer of data in real-time. Intelligent Transport System applications are supported by systems relying on Dedicated Short-Range Communications (DSRC) that consist of Road Side Units (RSUs) and On Board Units (OBUs) with transceivers and transponders [1]. V2V communication uses IEEE 802.11 or ITS-G5A/B/D standards which operates in 5.9GHz with a bandwidth on 75MHz and a range of 1000m [2]. This paper presents the implementation steps for a vehicle to vehicle (V2V) communication system that intends to increase driver awareness of the surroundings in an emergency situation. Particularly, the system broadcasts basic safety warning messages between an emergency vehicle and other vehicles in the vicinity.

2 Technical Implementation

Relying on [3] we implemented a Basic Safety Message (BSM) that is used to exchange safety data regarding vehicle state. The message was broadcast routinely to surrounding vehicles and contained information regarding longitude, latitude and vehicle identity. In order to locate the vehicles we used an ``Adafruit ultime'' GPS antenna. Once their position was known, a raspberry pi 2 computer processing unit combined the coordinates with other onboard sensors (e.g., speed, heading, acceleration) to generate the required BSM data string. Once the BSM was generated, the message was wirelessly transmitted to another vehicle by using the NRF24l01 LNA wireless module.

In order to make sure that the broadcast BSM was properly obtained, we relied on a receiver with Dedicated Short Range Radio Communication (DSRC). The system also included a computer processing unit that was able to decode the BSM properly and a GPS antenna to verify the relative distance between the sending and the receiving device. In order to convey the message to the driver in an adequate way, we developed an in-vehicle interface to display the warning through a 12*2 LCD display.

3 Prototype Evaluation

The prototype was tested under both lab and real-life conditions. Under lab conditions the devices were able to show the intended emergency message. During the field test one device was positioned in a vehicle that was marked as an emergency car. The second one was located in a different vehicle. Both devices were capable of sending a message within a range of 20 meters. Furthermore, the range could be increased by adding a third device and using it to resend the message.

References

1. T. ETSI, "102 792:" Intelligent Transport Systems (ITS)," *Mitig. Tech. Avoid Interf. Eur. CEN Dedic. Short Range Commun. RTTT DSRC Equip. Intell. Transp. Syst. ITS Oper. In*, vol. 5.
2. L. Armstrong, "Dedicated short range communications (dsrc)," *-Line Available Www Lee-armstrong ComDSRCDSRCHomeset H Tm*, 2012.
3. *3iBS, Intelligent Innovative Integrated Bus System*.

Smartphone-Based Traffic Sign Detection Using OpenCV

Mohammad. S Aminian[1], Arman Allamehzadeh[2],
Mehran Mostaed[2] and Cristina Olaverri-Monreal[2]

[1]Vienna Technical University, Institute of Transport Planning and Traffic Engineering, Vienna, Austria.
[2]University of Applied Sciences Technikum Wien, Department of Information Engineering and Security, Höchstädtplatz 6, 1200 Vienna, Austria

m.s.aminian@hotmail.com,{arman4u, mehran.mostaed7}@gmail.com, olaverri@technikum-wien.at

Abstract. Neglect of the instructions of road traffic signs is one of the main contributing factors in road accidents. This paper shows the development of a TSD (Traffic Sign Detection) application for traffic signs that contain the red color on an Android platform using image processing techniques. The application displays detected traffic signs and assists the driver in not missing important traffic information.

Keywords: Traffic Sign Recognition, Advanced Driver Assitance Systems, Traffic Safety, Computer Vision

1 Introduction

Traffic accidents are among the leading causes of fatalities and injuries worldwide. Studies have shown that more than 90% of vehicle accidents are caused due to driver error. Neglect of the instructions of road traffic signs is one of the main contributing factors in road accidents. Advanced Driver Assistance Systems (ADAS) refer to those systems which support the driver in performing various driving tasks safely. Among them, Traffic Sign Recognition (TSR) systems offer significant information to the driver about the road restrictions and surrounding environment by detecting and recognizing the traffic signs along the way [1]. The prevalence of smartphones and the recent advances in their computational power and camera quality has provided a new platform for developing low cost ADAS applications. We present in this paper the development of a TSD (Traffic Sign Detection) application for traffic signs that contain the red color (mostly regulatory signs for “no entry” “stop” and “yield”) on an Android platform using image processing techniques. The application displays detected traffic signs and assists the driver in not missing important traffic information.

2 Technical Implementation

In order to develop the smartphone application for real time detection of specific traffic signs, we reviewed the recent research performed on TSR and the required theory for traffic sign detection. Based on the analysis, we adopted the most effective approach relying on the OpenCV computer vision library. Color-based methods rely on exclusive color specification of traffic signs, while shape-based methods take advantage of defined shapes of traffic sings [2]. However, much research combines both of the mentioned techniques to achieve higher precision in detection. The main steps involved in implementing the code for image processing consisted of image acquisition, region of interest calculation, segmentation, color detection, shape classification and sign detection [3]. A graphical user interface that included checkboxes and push-buttons completed the proposed application.

3 Results

In this paper, we proposed an application to monitor the road for traffic sign detection using mobile smart devices. Evaluation results showed a high object detection rate (84 %) within a few milliseconds of time. The detection time differed depending on the resolution of the device used. A higher resolution needed more time to process the higher number of pixels, but the detection was more precise. The number of false detections could be reduced by improving the app in future work.

References

1. A. Mogelmose, M. M. Trivedi und T. B. Moeslund, „Vision Based Traffic Sign Detection and Analysis for Intelligent Driver Assistance,“ IEEE transactions on Intelligent Transportation Systems, pp. 1484-1497, 2012.

2. A. Ellahyani, M. El Ansary und I. El Jaafari, „Traffic sign detection and recognition based on random forests,“ ELSEVIER Applied Soft Computing, pp. 805-815, 2015.

3. M. Hannan, S. Wali, A. Hussain und S. Samad, „Comparative Survey on Traffic Sign Detection and Recognition: a Review,“ Przegląd Elektrotechniczny, pp. 38-42, 2015.

Optimization-based Approach for Cooperation and Coordination of Multi-autonomous Vehicles

Submitted to "Intelligent Transportation Systems and Smart Mobility" Workshop

Ahmed Hussein, Pablo Marín-Plaza, Fernando García, José María Armingol

{ahussein, pamarinp, fegarcia, armingol}@ing.uc3m.es
Intelligent Systems Lab (LSI) Research Group,
Universidad Carlos III de Madrid (UC3M), Madrid, Spain

Abstract. This abstract paper introduces a hybrid optimization-based approach to solve the Multi-Robot Task Allocation (MRTA) problem. This approach can coordinate among several intelligent vehicles and aid in the cooperation for better overall performance. The algorithm is to be implemented on autonomous golf-carts and tested in off-road environments within real-life scenarios. Several experiments are to be carried out and compared against another approaches, this is to ensure the credibility and the efficiency of the proposed approach.

1 Introduction

According to the World Health Organization (WHO), road traffic accidents are ranked number one as the main cause of death among young people [1]. The majority of these accidents are caused because of the human-error, due to the many distractions surrounding the drivers and pedestrians as well. Many solutions are proposed to reduce the number of accidents on the road, and one of these leading solutions is having self-driving vehicles [2]. Nowadays several car manufactures introduce their intelligent vehicles to the roads for public use. However, the more intelligent vehicles are on the road, the more cooperation and coordination among them are required.

In reference to the results from the current literature review, the coordination and cooperation among mult-agent systems can be modeled as Multi-Robot Task Allocation (MRTA) problem. MRTA problem is NP-hard, accordingly using an optimization-based approach to solve it is recommended [3]. This paper discusses the advantage of applying a hybrid meta-heuristic optimization algorithm to solve MRTA problem, and the following section 2 describes the proposed optimization-based approach to solve MRTA problem.

2 Proposed Approach

MRTA problem is one of the challenging problems in multi-robot systems, it can be seen as an optimal assignment problem. At which the goal is to find the best assignment for a set of robots to a set of tasks in such a way that optimizes the overall system performance, subjected to a set of constraints. The problem is modeled as multi-Traveling Salesmen Problem (mTSP), where the robots are considered as salesmen and the tasks are the same as cities. The formulation scheme is set to single-task robots, multi-robots tasks and time-extended tasks in a decentralized paradigm. From the current state-of-the-art, it was found that various optimization techniques have been used to solve the general task allocation problems and MRTA problem as well.

Two main optimization approaches obtained the best results in term of computational time and final assignment solution cost, they are the Simulated Annealing (SA) and the Genetic Algorithm (GA) approaches. However, each algorithm have a disadvantage, thus a combined hybrid approach is proposed to overcome these disadvantages, and accordingly it enhances the overall process.

The proposed approach is to be implemented in multiple autonomous golf-carts, which are equipped with the necessary sensors and actuators to navigate without any human intervention from one point to another. The vehicles are part of the Intelligent Campus Automobile (iCab) project [4]. Several experiments are to take place in an off-road environment, simulating various real-life scenarios. Moreover, in order to proof the credibility of the proposed approach, it will be tested on a well-known TSP test-bench and compared against other approaches under the same conditions.

Acknowledgments

This research is supported by Madrid Community through project SEGVAUTO-TRIES (S2013-MIT-2713), and the Spanish Government through the CICYT projects (TRA2015-63708-R and TRA2013-48314-C3-1-R).

References

1. WHO, "WHO global status report on road safety 2013: supporting a decade of action". World Health Organization, 2013.
2. A. Hussein, F. Garcia, J.M. Armingol and C. Olaverri-Monreal, "P2V and V2P Communication for Pedestrian Warning on the basis of Autonomous Vehicles". In proceedings of IEEE International Conference on Intelligent Transportation Systems (ITSC), pp. 1-6, 2016.
3. A. Khamis, A. Hussein, and A. Elmogy, "Multi-Robot Task Allocation: A Review of the State-of-art". Chapter in Cooperative Robots and Sensor Networks Systems, pp. 31-51, 2015.
4. A. Hussein, P. Marin-Plaza, D. Martin, A. de la Escalera and J.M. Armingol, "Autonomous Off-Road Navigation using Stereo-Vision and Laser-Rangefinder Fusion for Outdoor Obstacles Detection". In proceedings of IEEE Intelligent Vehicles Symposium (IV), pp. 104-109, 2016.

Stereo Vision-Based Convolutional Networks for Object Detection in Driving Environments

Carlos Guindel, David Martín, and José María Armingol

Intelligent Systems Lab., Universidad Carlos III de Madrid, Leganés, Madrid, Spain
{cguindel, dmgomez, armingol}@ing.uc3m.es

Abstract. Advanced driver assistance systems (ADAS), as well as autonomous vehicles, rely on object detection algorithms to enable a full understanding of the traffic scene. This work proposes a vision-based approach for on-road object detection which incorporates stereo information, frequently available in ADAS, within the framework provided by a state-of-art deep learning algorithm.

Keywords: deep learning, stereo vision, object detection

1 Introduction

Deep learning has become ubiquitous in almost every application involving object recognition in the past few years, intelligent transportation systems being no exception. Thereby, a variety of applications have been lately approached through Convolutional Neural Networks (CNNs) and other similar techniques.

The hierarchical feature learning performed in the CNNs is frequently focused on the three color channels of the image, while additional information is not exploited. Nevertheless, stereo vision systems have proven to be a satisfactory alternative for obtaining useful depth information in driving environments over the past decades. Obstacle detection is particularly benefited by the spatial reasoning provided by the stereo systems [1].

While CNNs are ideally suited to object classification, fitting them in a complete object detection scheme remains a very active research field. Lately, designs based on "attention" mechanisms are becoming popular. Faster R-CNN [3], a natural evolution of the previous R-CNN approach, is one of the most notorious. It provides an end-to-end framework whose results are comparable with more complex approaches. However, hypothesis generation remains a strong limiting factor in performance, particularly when a high overlapping is required.

We aim to enhance the state-of-the-art detection and classification framework provided by Faster R-CNN by leveraging depth information in a simple, straightforward way. Our proposed approach is shown in Fig. 1.

Depth information is appended to the RGB image as a fourth channel, in which each pixel is given a value proportional to its estimated disparity value. Stereo matching is performed through the widely known SGBM method. In order to avoid spurious errors introduced by non-defined values, a simple background interpolation is applied beforehand.

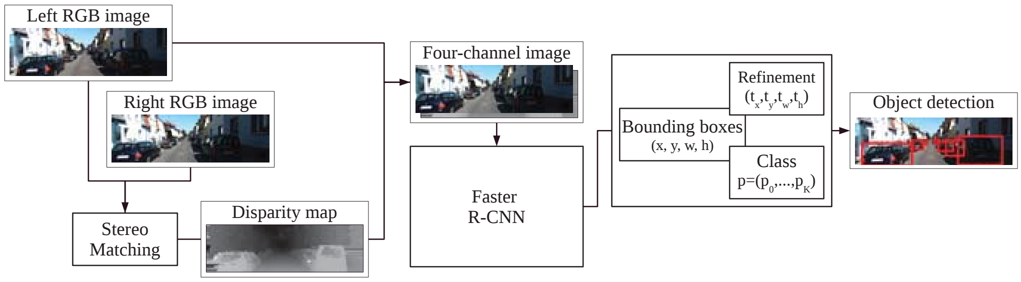


Fig. 1. Proposed object detection system.

We adopt VGG-16 as the CNN architecture. Experiments are performed on the KITTI dataset. To this end, the publicly available training set was conveniently divided into two splits, for training and evaluation. Table 1 compares our approach against the vanilla Faster R-CNN approach.

Table 1. Detection mAP (%) obtained on the KITTI validation set.

Input image	Easy	Medium	Hard
RGB	79.98	66.46	57.53
RGB+Disp.	80.84	66.64	58.03
ΔmAP	**+0.86**	**+0.18**	**+0.50**

This work is intended to be the first step towards a full scene understanding system based on the information given by the detected traffic participants, aimed to be integrated into the IVVI 2.0 [2] intelligent vehicle.

Acknowledgments Research supported by the Spanish Government through the CICYT projects (TRA2015-63708-R and TRA2013-48314-C3-1-R), and the Comunidad de Madrid through SEGVAUTO-TRIES (S2013/MIT-2713). The Tesla K40 used for this research was donated by the NVIDIA Corporation.

References

1. N. Bernini, M. Bertozzi, L. Castangia, M. Patander, and M. Sabbatelli. Real-time obstacle detection using stereo vision for autonomous ground vehicles: A survey. In *IEEE International Conference on Intelligent Transportation Systems (ITSC)*, pages 873–878, 2014.
2. D. Martín, F. García, B. Musleh, D. Olmeda, G. A. Peláez, P. Marín, A. Ponz, C. H. Rodríguez Garavito, A. Al-Kaff, A. de la Escalera, and J. M. Armingol. IVVI 2.0: An intelligent vehicle based on computational perception. *Expert Systems with Applications*, 41(17):7927–7944, 12 2014.
3. S. Ren, K. He, R. Girshick, and J. Sun. Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks. In *Advances in Neural Information Processing Systems (NIPS)*, 2015.

A simple classification approach to traffic flow state estimation

Aitor del Pino Saavedra Hernández[1], Javier J. Sánchez Medina[1], and Luis Moreira-Matías[2]

[1] CICEI – ULPGC, Spain
adritor8994@gmail.com, javier.sanchez@ulpgc.es.
[2] NEC Laboratories Europe,Heidelbert, Germany
luis.matias@neclab.eu

One of the most important elements regarding urban mobility is traffic management. Mobility has a great influence in citizens lives for many reasons. To name a few, it affects security, efficiency, sustainability and environmental impact. Thus, it is required to equip mobility managers with proper tools to get a precise idea about the current traffic situation and also to estimate its future state. These tools essential to facilitate their decision-making process.

The aim of this work is at creating a congestion prediction model for the Portuguese city of Porto based on FCD. To obtain such traffic model it has been applied the Knowledge Discovery in Databases (KDD) process, which comprises the following phases: data pre-processing, data mining and interpretation and model evaluation.

In the first step of the KDD process we selected the most suitable attributes. Also, samples with missing and/or erroneous values were filtered. After that, we did a transformation of that dataset using a grid in order to discretize the spatial coordinates using a well-known preprocessing tool: grid decomposition ([1]). Each cell consisted on a max and min lattitude and longitude selection, also sampling by the hour of the day and the day of the week. After that we split the original dataset into N dataset spatio-temporal 3D datasets, assigninig all GPS samples to each one of the aforementioned cells. Moreover, a few statistics were obtained for each cell, regarding occupancy, inflow and outflow of vehicles.

As a final task in this preprocessing stage we tagged each cell. We assigned each cell one of the three possible congestion states, namely Free, Synchronized and Congested. We did that using an analogy to the fundamental diagram of traffic flow (1). In that diagrams there is the so called critical point. It means a density value corresponding to the maximum traffic flow value. That point is commonly used as marker for determining when a traffic network is considered to be congested (beyond that density value). We made an analogy to label our cells in a similar way.

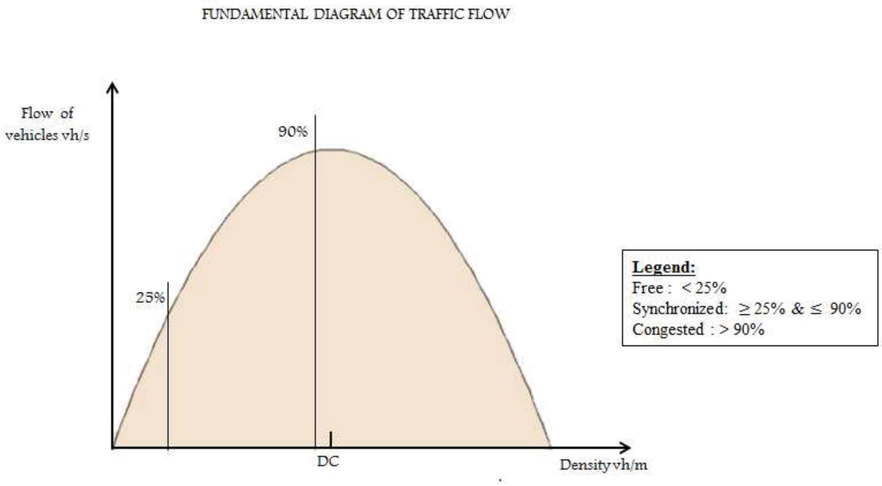


Fig. 1. Fundamental diagram of traffic flow.

After the preprocessing, we worked to obtain a classification model for each one of that cells in order of using it as a predictor of future congestion all around Porto city. We performed a set of experiments to evaluate a number of classification and evaluation algorithms, always using 10-folded crossvalidation because of the limited number of samples per cell.

The best model was obtained when we only adjust the parameters of the classifier Bagging + C.4.5. We also evaluated other metrics like the model consistency (variance reduction) and Multiclass Area Under the Curve metric ([3]).

Finally, in the last stage of the Knowledge Discovery in Databases process we made a simple interface to visually inspect the resulting predictions.

The dataset used for this work is the same published here ([2]) and was built by capturing GPS positions from 442 taxis, acting as probe vehicles for this purpose. Every 15 seconds a GPS sample was stored, every time a passenger hired a ride to some place in that city. Results obtained were encouraging: A classification accuracy of 82.5%.

References

1. Castro, P.S., Zhang, D., Chen, C., Li, S., Pan, G.: From taxi gps traces to social and community dynamics: A survey. ACM Computing Surveys (CSUR) 46(2), 17 (2013)
2. Moreira-Matias, L., Gama, J., Ferreira, M., Mendes-Moreira, J., Damas, L.: Predicting taxi x2013;passenger demand using streaming data. IEEE Transactions on Intelligent Transportation Systems 14(3), 1393–1402 (Sept 2013)
3. Tang, K., Wang, R., Chen, T.: Towards maximizing the area under the roc curve for multi-class classification problems (2011)

SUMO Performance Comparative Analysis: C vs. Python

Samuel Romero Santana[1], Javier J. Sanchez-Medina[1], Itziar Alonso-Gonzalez[23], and David Sanchez-Rodriguez[23]

[1] CICEI – Department of Computer Science – ULPGC, Spain
sam_r_s@hotmail.com, javier.sanchez@ulpgc.es.
[2] Department of Telematic Engineering
[3] Institute for Technological Development and Innovation in Communications
itziar.alonso@ulpgc.es, david.sanchez@ulpgc.es

Mobility is an essential part of modern societies. Urban mobility has three important goals, namely Safety, Efficiency and Sustainability. Modern cities have a number of challenges ahead. To name a few, population levels are increasing together with increments in pullution, energy demand and environmental impact.

A very important element within urban mobility is Traffic Simulation[4]. There is no doubt about the importance of the development of accurate traffic simulations in particular for an efficient traffic management and planning. In that context, there is an outstanding tool, SUMO (Simulation Urban Mobility)[3][1], which is not only a complete and customizable microsimulation platform. It is also changing the game rules with its open software approach. Its community of developers is very alive and growing every month, likewise the number of research groups that embrace this tool as main technology for their research plans.

However, SUMO still lacks of something that will be clearly a deal breaker for local administrations regarding other tools and platforms [3][1]. That is performance. Traffic networks are generally very big and computationally expensive to simulate. Realtime performance levels are needed for on-line use.

In our lab we are aiming at the parallelization of SUMO, but before of that move, we are evaluation the performance improvement through shifting from Python to ANSI C as programming language.

We have studied how SUMO works. SUMO makes its calculations in Phyton[2]. Phyton is a high level multi-platform programming languaje. Its object oriented approach and its portability may yield an inncecessary headover regarding SUMO performance.

We use python because the SUMO engine is implemented in that language, and researchers when want to communicate with SUMO through TraCI use that high level language. However, here we present some promissing results using C for several modules. In this work we compare two versions of SUMO, the out-of-the-box based on Python and a second one, developed in our lab with some modules in C instead. We present a performance comparison study, using that two versions of SUMO.

For our experiments we have used a simple network, consisting of in a two lanes motorway. We simulated a vehicle flow, between fifty and one hundred cars driving along that motorway during five seconds. That vehicles drive along the motorway in a constant speed and don't have to take any decision along the way.

Results are encouraging. We have evaluated the application speed-up by doing an arithmetic average of thirty simulations in both SUMO versions, varying the number of vehicles.

Fig. 1. C vs Python

In figure 1 we represent the number of simulated vehicles in the horizontal axis. In the vertical axis we see the averaged execution time in miliseconds. As we can see, C has a clearly better response, and at lease in this range, there seems to be a clearly linear relationship between both variables. For every test, C is faster than Python.

As a future plan, we are preparing more extensive experiments, varying the type of vehicles, number of lanes, streets, highways, to see if in harder conditions we get consistent results regarding both versions of SUMO. Also, we plan to translate some more modules and funcionalities from Python to SUMO before the parallelization of that platform. We have already designed the parallel architecture and we will share the main elements it will include.

References

1. Behrisch, M., Bieker, L., Erdmann, J., Krajzewicz, D.: Sumo-simulation of urban mobility-an overview. In: SIMUL 2011, The Third International Conference on Advances in System Simulation. pp. 55–60 (2011)
2. Dobesova, Z.: Programming language python for data processing. In: Electrical and Control Engineering (ICECE), 2011 International Conference on (2011)
3. Romero Santana, S., Sanchez-Medina, J.J., Rubio-Royo, E.: How to simulate traffic with sumo. In: Computer Aided Systems Theory EUROCAST 2015 (2015)
4. Romero Santana, S., Sanchez-Medina, J.J., Rubio-Royo, E.: Platoon driving intelligence. a survey. In: Computer Aided Systems Theory EUROCAST 2015 (2015)

Flexible hierarchical feedback control of urban traffic

Zhenzhen Hao[1,3], René Boel [⋆,2,3], Yaqi Zhu[3]
Chris Manzie[3], Iman Shames[3], and Zhiwu Li[1]

[1] School of Electro-Mechanical Engineering, Xidian University, Xi'an, 710071, China
[2] SYSTeMS Research group, Faculty of Engineering, Ghent University, Belgium
[3] School of Engineering, The University of Melbourne, Australia

Abstract. This paper proposes a scalable traffic responsive hierarchical control system for optimizing the flow of vehicles through a large urban network. The network is partitioned into several regions, in order to reduce the computational complexity of the design and of the implementation of the coordinated feedback controller. Coordination between regions is realized at a slow time scale through perimeter control, preventing congestion and performance collapse by keeping the number of vehicles in each region below the maximum flow density in the macroscopic fundamental diagram (MFD) for that region. At a fast time scale a cell transmission (CTM) urban traffic model is used for designing a strategy coordinating local feedback controllers (e.g. classical traffic lights, but the method can be applied also for controllers using I2V communication, or for autonomous vehicles) in each region. It is shown that these controllers can adjust the the macroscopic fundamental diagram (MFD) for the region, improving the performance of perimeter control.

Keywords: urban traffic control, hierarchical control, coordinated control, cell transmission model, perimeter control

1 Description of proposed methodology

Consider a large urban area $\mathcal{U} = \bigcup_{i=1\ldots I} Reg_i$ where the conflicts between the interacting traffic streams are resolved by traffic responsive control actions. In order to allow computationally efficient design of the control strategies hierarchical decomposition of the problem can be used [?]. In line with this approach we propose using perimeter control controlling the flow entering Reg_i through its boundaries with neighbouring regions in order to avoid congestion in Reg_i. Coordinated local feedback control optimizes traffic flow inside each Reg_i at a faster time scale. Currently traffic lights are used as actuators, using information from loop detectors, video cameras and radars to select red/green switching times. But in the future additional communication via I2V and V2I infrastructures will enable more sophisticated strategies, like advisory speeds, or even fully

⋆ corresponding author: rene.boel@ugent.be

controlled speed for autonomous vehicles. In order to simplify the presentation we discuss our control design paradigm below assuming traffic lights are used, but the extension to other control actuators is obvious. The goal of the feedback strategies is to reliably and robustly minimize average delay for all participants in the traffic. The proposed method allows distinction between different modes of traffic, e.g. in order to give priority to emergency vehicles and to public transportation, and leads to smooth traffic behaviour, improving safety and reducing pollution.

Perimeter control [4], [3] avoids the unstable right branch of the MFD_i of Reg_i by reducing the inflow to Reg_i when the number of vehicles in Reg_i approaches the maximum of MFD_i. In [2] distributed feedback control laws select the inflow to Reg_i as functions of the number of vehicles in Reg_i and in its neighbours. The choice of the stable operating point, achieving low delay, depends on the shape of the MFD [4]. MFDs with a high maximum, for as high a traffic density as possible, improve the system performance. In [4] a selection of an appropriate member of a library of preplanned settings of the traffic lights is used for this purpose.

Improving MFD_i requires a combination of the efficiency of pretimed green waves and of the robustness and responsiveness of feedback controllers.We propose (for more details see [1]) that coordinated MPC controllers of the switching times of the traffic lights inside Reg_i can improve the shape of MFD_i. Our MPC approach uses predictions of traffic arriving at the intersections in Reg_i over a horizon of a few cycles of the traffic light, and selects the switching times of the traffic lights that minimize the waste of capacity. These predictions at each intersection depend on planned control actions at neighbouring intersections, thus ensuring proper coordination. The predictions use a novel computationally simple CTM (cell transmission) model for urban traffic, including upstream and downstream effects as in classical CTM, as well as queue discharge delay and effects of red lights. In [1] we show that, even for rather simple cases with limited scope for improvement, these strategies can speed up the flow of vehicles out of the region leading to improved MFDs. The proposed decomposition partitioning $\mathcal{U} = \bigcup_{i=1,\ldots,I} Reg_i$ into I regions Reg_i renders the design tool scalable.

References

1. Z. Hao, R. Boel, Z. Li, C. Manzie, I. Shames, Y. Zhu: Hierarchical control of urban traffic using regional control dependent fundamental diagrams, under preparation
2. Y. Zhu, I. Shames, C. Manzie: Stability Analysis for Distributed perimeter Controlled Traffic networks, 2016 American Control Conference, pp.809-814
3. K.Abodoulas, N. Geroliminis: Perimeter and boundary flow control in multi-reservoir hetrogeneous networks, transportation research part B: methodological, 55, 265-281, 2013
4. M. Hajiahmadi, J. Haddad, B. De Schutter, N. Geroliminis: Optimal Hybrid Perimeter and Switching Plans Control for urban Traffic Netweorks, IEEE-T-Control Systems technology, 23, 2, pp.464-478, 2015
5. N. Geroliminis, C. Daganzo: Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings, working paper UCB-ITS-VWP-2007-5

Dynamic Ambulance Routing for Disaster Response

Jesica de Armas, Eduardo Lalla-Ruiz, and J. Marcos Moreno-Vega

Department of Economics and Business
Universitat Pompeu Fabra. Barcelona, Spain
jesica.dearmas@upf.edu

Institute of Information Systems
University of Hamburg. Hamburg, Germany
eduardo.lalla-ruiz@uni-hamburg.de

Department of Computer Engineering and Systems
University of La Laguna. La Laguna, Spain
jmmoreno@ull.es

1 Introduction

Emergency logistics refers to systems and procedures devoted to manage the distribution of aid by means of resources and specialists to areas affected by a man-made or natural disaster. The main aim in those situations if to provide an urgent relief. In this work the Ambulance Routing Problem (ARP) proposed by Talarico *et al.* [2] that arises in a disaster response scenario is addressed. This problem considers a set of equal ambulances, K, a set of patients, P, which is divided into a subset of red code patients, R, and a subset of green code patients, G, such that $P = R \cup G$, and a set of hospitals, H. Each hospital $h \in H$ counts with a number of ambulances K_h such that $\sum_{h \in H} K_h = |K|$. Moreover, in order to provide an appropriate aid to the injured persons different type of actions have to be performed. Namely, depending on the severity of the injury, different types of patients arise:

- Set of red code patients (R): It is composed by those patients that are seriously injured and need to be brought to a hospital by an ambulance.
- Set of green code patients (G): It is composed by those patients that are slightly injured and can be helped directly in the field for a given amount of time $d_i, i \in G$.

Therefore, according to the previous classification, ambulances have to perform different actions. Namely, in the case of a red code patient the ambulance has to depart either from a hospital or from its current position in the given scenario and bring him/her to a hospital. On the other hand, in the case of green code patients the ambulance has to reach that injured person and provide an assistance for a given time d_i without needing to return to the hospital.

As can be noticed, a wealth of combinations of actions to be performed by the ambulances emerges in order to minimize a given objective function. In this regard, the quality of a solution for the ARP is evaluated by means of the weight service completion time for all red code patients and the latest service completion time among all green code patients.

2 Dynamism in the Ambulance Routing Problem

The static problem (*i.e.* the problem not considering any changes or additional events besides the initial data) has been solved in the literature using a Large Neighborhood Search (LNS) [2]. Nevertheless, the ambulance routing problem appears in a context with a particular tendency to dynamism, since patients could change their condition or new patients could appear meanwhile ambulances are developing their routes. Following the nomenclature given in [2], the patients who can be assisted directly in the field are green code patients, and those who need to be brought to hospitals are red code patients. Thus, we can define three different kinds of dynamic events that could come up over the time horizon:

- Either new green or red patients appear along the execution of a given response plan and have to be incorporated in the solution that are working.
- A green patient becomes a red patient due to unforeseen difficulties, this leads to changes in the assistance and service provided by the ambulances. For instance, a green patient converted to red would make the ambulance to return to the hospital.
- Either a green or red patient deactivates due to other sources of assistance.

These three kinds of dynamism have to be taken into account in order to properly offer medical aid while improving the quality of the assistance and schedules provided. In this sense, to the best of our knowledge, this problem with this special casuistry has not been tackled in the literature. For this reason, the goal of this work is two-fold. On the one hand, a particular implementation of a Variable Neighborhood Search (VNS, Hansen and Mladenovic [1]) is proposed to solve the initial static problem and, on the other hand, the dynamic version of the problem is dealt extending the above-mentioned VNS implementation.

References

1. P. Hansen, N. Mladenovic, and J.A. Moreno Perez. Variable neighbourhood search: methods and applications. *Annals of Operations Research*, 175(1):367–407, 2010.
2. Luca Talarico, Frank Meisel, and Kenneth Sörensen. Ambulance routing for disaster response with patient groups. *Comput. Oper. Res.*, 56(C):120–133, April 2015.

Study of the lane change maneuver: automated driving use case

Ray Lattarulo and Joshué Pérez

Tecnalia Research and Innovation,
Parque Científico y Tecnológico de Bizkaia, Geldo Auzoa, Edif. 700, 48160 Derio, Bizkaia
{rayalejandro.lattarulo,joshue.perez}@tecnalia.com
www.tecnalia.com/en/

Extended abstract

Nowadays, the idea of a completely interconnected city with infrastructure, vehicles and even the humans on a connectivity loop is a reality. They are commonly found on the people's everyday life. For instances, smart phones applications are capable to interact with the some city devices, and even with automated driving functions. All these characteristic have been well-received by users around the world, even the idea of automated vehicles. Some studies shows than 55 percent of the population would like to take rides on automated vehicles and even more than 65 percent on a partly automated vehicle [1].

With the evolution of the Intelligent Transportation Systems (ITS) in the last decade, a great variety of ADAS systems have been tested accomplishing the deployment of them in commercial vehicles as: lane departure warning and assistance, automatic parking, blind spot monitoring, among others. Most of them are based on on-board sensors as radars, LiDAR, cameras, ultrasonic sensors and communication V2X [2]. But in the case of a complete automated driving there are still a great variety of different scenarios to be tested to accomplish the commercial deployment of a SAE level 4 and 5 of automation [5].

Great varieties of tests related have been performed on highways. However, planning constrains and control techniques have been implemented but not in an extensive way as the first two cases [3]. One of the big and interesting challenging scenarios is the lane change maneuver. This scenario is defined by a series of constrains and conditions given by the perception systems, as detection of the environment and obstacles, and others of control part, as speed considerations and even communication with another vehicles.

On the current paper, the control architecture implemented was made based on [4] and the approaches are related with the behavioral planner on the decision block for the Lane Change maneuver on Highways. We are considering the information obtained from the sensors as frontal LiDAR and cameras to detect obstacles on the road, and communication with other vehicles to coordinate in a cooperative way the maneuver.

Three possible stages were established to validate the maneuver. The first is the generation of a parametric (continuous) curve to change the lane, considering

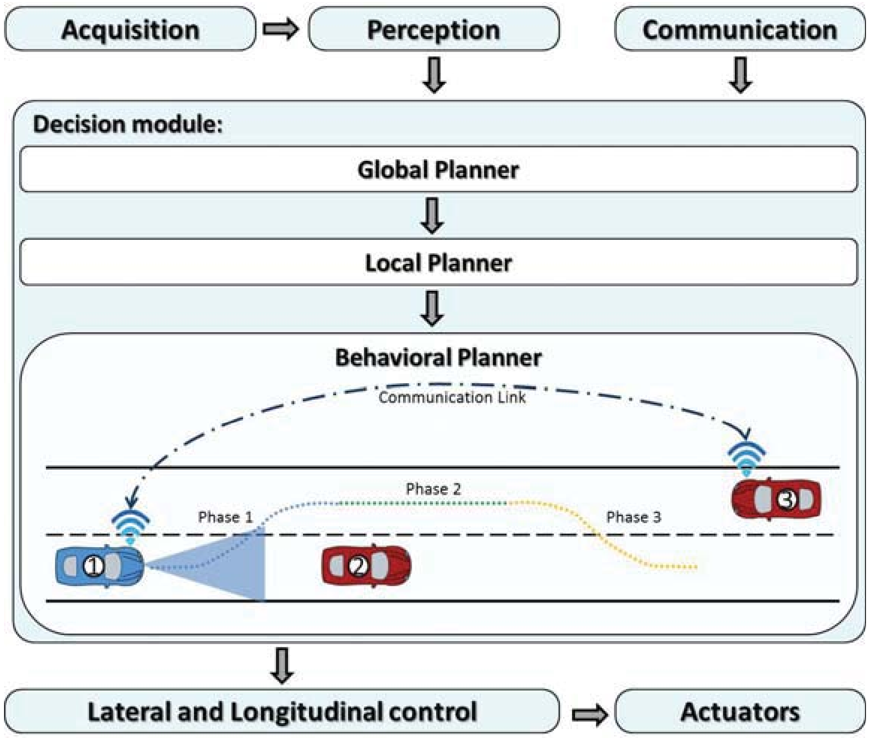


Fig. 1. Control architecture in detail with obstacle avoidance.

the possibilities that a vehicle could come on the opposite direction and the total time to recreate the maneuver. The second stage is to overtake the other vehicle in the opposite lane (adding a secure distance in front of the overtaken vehicle) and the third stage is the return of the vehicle to the lane.

The implementation of these algorithms and the control architecture was performed in a simulator based on simulink, and with the capabilities of simulated the dynamics of the vehicle, called Dynacar [6].

ACKNOWLEDGMENT

This work is partly supported by the H2020 project UnCoVerCPS with grant number 643921.

References

1. Boston consulting group, "Self-driving vehicles, robo-taxis, and the urban mobility revolution". Constumer survey Q3 2015 and World Economic Forum.
2. Khan, J. : "Using ADAS sensors in implementation of novel automotive features for increased safety and guidance". 3rd International Conference on Signal Processing and Integrated Networks (SPIN). Pp. 753 - 758. 2016.

3. Perez, J., Lattarulo, R., Nashashibi, F.: "Dynamic trajectory generation using continuous-curvature alorithms for door to door assistance vehicles". IEEE Intelligent Vehicle Symposium (IV). Pp. 510 - 515. 2014.
4. Gonzalez, D., Perez, J., Milanes, V. and Nashashibi, F.: "A review of motion planning techniques for automated vehicles". IEEE Transaction of intelligent transportation systems. Pp. 1135 - 1145. 2015.
5. SAEJ3016: "Taxonomy and Definitions for Terms Related to On Road Motor Vehicle Automated Driving Systems". SAE International. 2014.
6. Iñaki Iglesias: "Herramienta para acelerar el desarrollo de nuevos sistemas y controles para automocin". Revista Automática e Intrumentación. Pp. 45 - 49. Vol. 478. 2015.

Effects of Cooperative Lane-Change Behaviour on Vehicular Traffic Flow

Christian Backfrieder[1], Gerald Ostermayer[1], Manuel Lindorfer[1] and Christoph F. Mecklenbräuker[2]

Research Group Networks and Mobility, UAS Upper Austria, Hagenberg, Austria
{christian.backfrieder,manuel.lindorfer,gerald.ostermayer}@fh-hagenberg.at
Christian Doppler Lab Wireless Technology for Sustainable Mobility, Vienna University of Technology, Vienna, Austria
cfm@nt.tuwien.ac.at

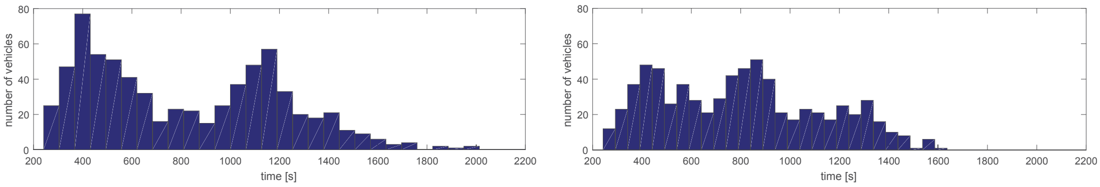
1 Introduction

Beyond doubt, behaviour of drivers has a strong impact on vehicular traffic flow. In order to investigate those effects, i.e. gains and losses resulting from more or less cooperative behaviour, simulations are an expedient to quantify those effects in numbers. Comprehensive simulations include road networks containing roads with multiple lanes. The discrete decision making of single vehicles whether or not to change their lane is influenced by multiple factors, and often controlled by lane-change models of different types. Obviously, the decision is depending not only on the demand to stick to traffic rules, but also to follow the own route and gain speed advantage by overtaking others. Additionally, the reaction to other, neighbored vehicles' requirements may trigger the consideration of lange changes. To do so, influence on the current speed and acceleration may be necessary to execute the lane-change. A cooperative lane-change model considering the discussed issues is presented in [1]. It acts as extension to both lane-change (e.g. MOBIL [2]) and longitudinal models and especially provides solutions for situations where cooperation between vehicles is necessary. However, it does not present and quantify potential gains and advantages resulting from cooperative behaviour compared to egoistic lane-change models. This paper presents simulation results, which show in which situations cooperation is beneficial and how much resources can be saved as a consequence. It reveals benefits when using cooperative lane-change behaviour, especially in terms of average time consumption of vehicles to get from source to destination. Additionally, another unrealistic effect of non-cooperative models can be counteracted, that is not visible when averaging time and fuel consumption: Single vehicles are convicted to wait for a very long time, because it is impossible to change to the target lane in dense traffic. If the blocking vehicle on the target lane considers also its neighbors, the neighbor vehicle can change lane after a short waiting time and continue its ride, what moves simulation results closer to reality.

2 Investigation and Simulation Results

The simulations were carried out using different scenarios, configured within the microscopic traffic simulator TraffSim [3]. Within the scope of this investigation, multiple situations where cooperative behaviour is essential were set up, like an overloaded highway exit or intersections with turn lanes. The simulation results show that cooperative behaviour leads to reduction of average travel time and fuel consumption in all investigated situations. For this abstract, representative results were picked to demonstrate the performance improvements. The scenario consists of a traffic light with four connected road segments and multiple lanes, including turn restrictions and therefore necessity of lane-changes for some of the vehicles to reach the desired destination. Results reveal improvements of 1.54 % average fuel consumption over all vehicles and 1 % less average time consumption for this example scenario. These improvements can completely be associated with the cooperative lane-change behaviour, and less waiting times after standstill due to consideration of neighbor vehicles' needs.

Additionally, the travel time distribution is more balanced, due to avoidance of very long waiting times for single vehicles due to blocked highway exit lanes, which is revealed in histograms over travel time in figure 1.



(a) Non-cooperative behaviour (b) Cooperative behaviour

Fig. 1. Travel time distribution with different behaviour settings

Acknowledgments This project has been co-financed by the European Union using financial means of the European Regional Development Fund (EFRE). Further information to IWB/EFRE is available at `www.efre.gv.at`.

References

1. Backfrieder, C., Ostermayer, G., Lindorfer, M., Mecklenbräuker, C.F. In: Cooperative Lane-Change and Longitudinal Behaviour Model Extension for TraffSim. Springer International Publishing, Cham (2016) 52–62
2. Kesting, A., Treiber, M., Helbing, D.: General Lane-Changing Model MOBIL for Car-Following Models. Transportation Research Record: Journal of the Transportation Research Board (January 2007) 86–94
3. Backfrieder, C., Ostermayer, G., Mecklenbräuker, C.: Extended from EMS2013. TraffSim - a traffic simulator for investigations of congestion minimization through dynamic vehicle rerouting. International Journal of Simulation- Systems, Science and Technology- IJSSST V15 (January 2015)

Comparative Performance Analysis of Variable Speed Limit Systems Control Methods Using Micro-Simulation: A Case Study on D100 Freeway, Istanbul

Mohd Sadat, Ismail M. Abuamer, Mehmet Ali Silgu and Hilmi Berk Celikoglu

Department of Civil Engineering at Technical University of Istanbul (ITU), Istanbul, Turkey
{sadatm, ismailmaabuamer, msilgu,celikoglu}@itu.edu.tr

Abstract. In this paper, we implement two Variable Speed Limits (VSL) control strategies at a bottleneck on D100 freeway in micro-simulation environment of VSSIM, which is calibrated with field data. We compare the performance of both the strategies with no control case.

Keywords. Variable Speed Limits; Congestion; Microscopic Traffic Simulation.

1 Introduction

Growing traffic on freeways has created demand for traffic control systems that can manage it efficiently without the need of expanding the infrastructure. Intelligent Transportation System techniques like Ramp Metering, Route Guidance and Variable Speed Limits (VSL) can help in easing out congestion on freeways. While ramp metering and route guidance system have limited scope of application ([1]), VSLs can be used for preventing traffic breakdown by regulating flow upstream of a congestion.

Studies with the aim of improving the homogeneity of flow have been done which results in better safety ([2]) but limited improvement in freeway performance. Model predictive control was used in [3] extending the METANET model to incorporate speed limits with aim of preventing the breakdown of traffic flow. The VSLs were used as the function of density in [3]. Similarly, a feedback control model for a single bottleneck using VSLs as function of occupancy in micro-simulation environment is developed in [4]. Control model based on flow, occupancy and speed was simulated in [5] using a micro-simulation environment. Most of the studies have been conducted using macro-simulation ([3]) and micro-simulation environment ([2, 4, 5]). Fixed control approaches based on occupancy, implemented on I-4 Orlando Florida, and flow, implemented on M-25 England, have been utilized in past. Studies have reported improved performance with better control strategies however mostly in hypothetical test scenarios. Aforementioned field implementation also used simple algorithms. Thus, this study presents a comparative performance evaluation of two control methods in VSLs implementation: One of the control measure is adapted and modified from [5], which is based on flow occupancy, and speed while other one is adapted from [4] based on feedback control based on occupancy to calculate VSLs.

Many segments of D100 freeway of Istanbul experience recurrent congestion ([6]). A section of D100 freeway, that has heavy congestion due to merging traffic from on-ramps, is chosen accordingly as the case to analyze in this study. Microscopic traffic simulation software VISSIM is used for modeling and simulating the traffic. Calibration of VISSIM is sought using Remote Traffic Microwave Sensor data provided by Istanbul Municipality. Parameters including, car following behaviour, headway and lane changing distances and lane changing behaviour ([7]) are tuned until real and simulated speed profiles match. GEH test is performed to validate the calibration. VISSIM is integrated with MATLAB via Component Object Model interface. Values of flow, density and volume are retrieved from VISSIM by MATLAB in real time. These values are used to determine the VSLs by running the control algorithms and are fed back to VISSIM. VSLs are applied as point and area application. While point application of VSL represents present day application methods, area application represent scenario when there is full Infrastructure to Vehicle (IV) connectivity.

The present study shows that both control methods reported better results when compared no control case in terms of flow, occupancy, speed and Total Travel Time through the selected network. Environmental impacts of the simulated traffic, in terms of emissions, are also found to be reduced. The feedback control strategy performed relatively better. Also the speed profile achieved with feedback control is more homogenized when compared to resultant speed profiles from the run of the algorithm used in [6]. It can also be concluded that application area of VSL, type of VSL application, position of signs and detectors affect the performance of VSL control systems.

References

1. Papamichail I, Kotsialos A, Margonis I, Papageorgiou M.:Coordinated ramp metering for freeway networks–A model-predictive hierarchical control approach. Transportation Research Part C: Emerging Technologies; 18(3):311-31. (June 2010)
2. Yu R, Abdel-Aty M.: An optimal variable speed limits system to ameliorate traffic safety risk. Transportation Research Part C: emerging technologies. 30; 46:235-46. (Sep 2014)
3. Hegyi A, De Schutter B, Hellendoorn H.: Model predictive control for optimal coordination of ramp metering and variable speed limits. Transportation Research Part C: Emerging Technologies. 30; 13(3):185-209. (Jun 2005)
4. Müller ER, Carlson RC, Kraus W, Papageorgiou M.: Microsimulation analysis of practical aspects of traffic control with variable speed limits. IEEE Transactions on Intelligent Transportation Systems. 16(1):512-23. (Feb 2015)
5. Allaby P, Hellinga B, Bullock M.: Variable speed limits: Safety and operational impacts of a candidate control strategy for freeway applications. IEEE Transactions on Intelligent Transportation Systems. 8(4):671-80. (Dec 2007)
6. Celikoglu HB, Silgu MA.: Extension of Traffic Flow Pattern Dynamic Classification by a Macroscopic Model Using Multivariate Clustering. Transportation Science.50 (3):966-81. (Feb 2016)
7. PTV A. VISSIM 5.40 user manual. Karlsruhe, Germany. (2011)

Bayesian Networks Probabilistic Safety Analysis of Highways and Roads

Elena Mora, Zacarías Grande, and Enrique Castillo

Department of Applied Mathematics and Computational Sciences,
University of Cantabria, 39005 Santander
elenamoravil@gmail.com, zgandrade@gmail.com, castie@unican.es

Extended abstract

A probabilistic safety analysis methodology based on Bayesian networks models for the probabilistic safety assessment (PSA) of highway and roads is presented. The main idea consists of (a) identifying all the elements encountered when travelling the road, such as light or speed limit signs, infrastructure, terrain, intersections, tunnels, viaducts, roundabouts, curves and any safety relevant elements, (b) reproducing these elements by sets of variables, such as, speed, weather conditions, visibility, vehicle types, driver's experience, etc., (c) identifying the direct dependencies among variables, (d) building a directed acyclic graph to reproduce the qualitative structure of the Bayesian network, and (e) building the conditional probability tables for each variable conditioned on its parent nodes.

Since human error is the most important cause of accidents, driver's tiredness and attention are used to model how the driver's behaviour evolves with driving and how it is affected by the environment, signs and other factors. In addition, in the model we have considered the following variables: driver's speed decision, driver's type, traffic intensity, vehicle type, speed, vehicle and pavement failures, collision, weather, signal state, driver's decisions, technical failures and incidents. After establishing the dependencies among the variables, the conditional probability tables are built to quantify the Bayesian network and to obtain the joint probability of all variables. Closed formulas for these tables are derived, which allow us to implement the model and to identify the particular contribution of each variable in a sensitivity analysis. A computer program developed in Matlab implements the Bayesian network model from the list of road items and a set of parameter values given by a group of experts. In this way, the most critical elements can be identified and sorted by importance, so that an improvement of the global safety of the road can be done savings time and money. Any maintenance program based on this set leads to an important saving of resources. Real examples of a Spanish highway and a conventional road illustrate the proposed methodology and show its main advantages with respect to alternative methods. One of these examples can be seen in Figure 1 illustrating the plots and graphical information provided by the program.

Among the original contributions of the paper we include: (a) a systematic and natural methodology presented for the PSA of highways in which the contribution of each element to safety is identified, (b) efficient closed formulas of the conditional probability tables, (c) a computer program to automatically built the Bayesian network based on a video of the road and an extra lab work where the items are identified, (d) a report including plots of the acyclic graph, a plot of the elements, a graphical representation of the cumulative expected number of severe incidents and a table with the risk associated with each item given to identify the most risky items, (e) a partitioning technique to reduce the complexity from non-linear to linear in the number of items or road length, and (f) some applications to real cases of roads and highways.

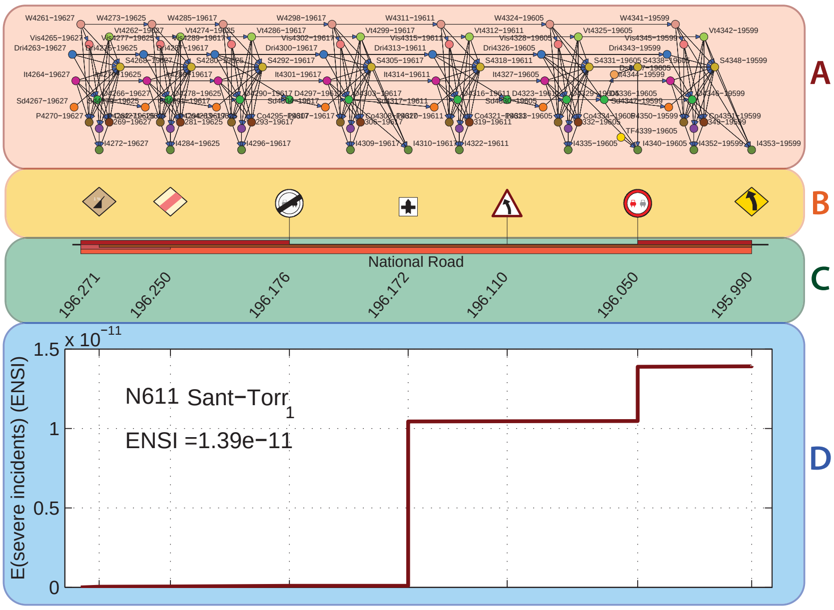


Figure 1.- Example of the information supplied by the computer program.

References

1. E. Castillo, Z. Grande, and A. Calviño. Bayesian networks based probabilistic risk analysis for railway lines. *Computer Aided Civil and Infrastructure Engineering*, 31:681–700, 2016.
2. E. Castillo, Z. Grande, and A. Calviño. A Markovian-Bayesian network for risk analysis of high speed and conventional railway lines integrating human errors. *Computer Aided Civil And Infrastructure Engineering*, 31:193–218, 2016.
3. E. Castillo, Z. Grande, A. Calviño, M. Nogal, and A. O'Connor. Probabilistic safety analysis of high speed railway lines including human errors. In J. Pombo, editor, *Proc. Third Intern. Conf. on Railway Technology: Research, Development and Maintenance*, number Paper 73, Stirlingshire, UK, 2016. Civil-Comp Press.
4. M. Deublein, M. Schubert, B. T. Adey, and B. de Soto García. A Bayesian network model to predict accidents on Swiss highways. *Infrastructure Asset Management*, 2(4):145–158, 2015.
5. M. K. Deublein. *Roadway accident risk prediction based on Bayesian probabilistic networks*. Ph. D., ETH Zürich, Zürich, 2013.
6. M. Pawlovich, W. Li, A. Carriquiry, and T. Welch. Experience with road diet measures: Use of Bayesian approach to assess impacts on crash frequencies and crash rates. *TRR: Journal of the Transportation R. B.*, 1953:163–171, 2006.
7. B. Persaud and C. Lyon. Empirical Bayes before-after safety studies: Lessons learned from two decades of experience and future directions. *Accident Analysis & Prevention*, 39(3):546 – 555, 2007.

Vehicular emissions based environmental impact assessment of transportation networks: a case study analyzing mobility patterns of a university campus

Mehmet Ali Silgu, Erdi Ozturk and Hilmi Berk Celikoglu

Department of Civil Engineering at Technical University of Istanbul (ITU), Istanbul, Turkey
{msilgu, ozturkerdi, celikoglu}@itu.edu.tr

Abstract. In this paper, we adopt an environmental impact assessment indicator to specify the emission-based environmental impacts of the vehicular traffic degradation on a network's link capacities to discuss the campus level mobility patterns.

Keywords. mobility; environmental assessment; network robustness; system-optimization; user-optimization

1 Introduction

In this paper, we adopt an environmental impact assessment indicator ([1]) in order to specify the emission-based environmental impacts of the vehicular traffic degradation on a network's link capacities by evaluating comparatively the user optimal and system optimal assignment principles ([2]). Initial numerical analyses are conducted considering a number of sample network topologies including the Sioux Falls network ([3]) as well a number of demand profiles. The emission-based environmental impact assessment is then extended to a real case study over the network of the Technical University of Istanbul Ayazaga Campus. In order to discuss the campus level mobility patterns in terms of: i- congestion due to on-road parkings; and ii- pedestrianization, a number network efficiency measures ([1]), specifically to indicate link performances, are utilized. Considering the within-day variation of campus demand the user equilibrium and the system optimal dynamic traffic assignments are sought over a simulation environment. Degradations on link capacities and link importance rankings are used to signify the probable outcomes of the campus traffic management policies as scenarios.

References

1. Nagurney A, Qiang Q: Robustness of transportation networks subject to degradable links. Europhysics Letters 80, 68001:1-6. (Nov. 2007).
2. Beckmann MJ, McGuire CB, Winsten CB.: Studies in the economics of transportation. Yale University Press, New Haven, Connecticut (1956).
3. LeBlanc LJ, Morlok EK, Pierskalla WP.: An efficient approach to solving the road network equilibrium traffic assignment problem. Transportation Research Part B: Methodological, 9(5): 309-318. (Oct. 1975).

Author Index